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The Fauna and Geography of the Maldive and Laccadive Archipelagoes

Being the Account of the Work carried on and of the Collections made by an Expedition during the years 1899 and 1900

Edited by

J. STANLEY GARDINER, M.A.

Fellow of Gonville and Caius College and late Balfour Student of the University of Cambridge.

VOLUME I. PART IV.

With Plates XVIII—XXV and Text-Illustrations 76—119

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CEPHALOCHORDA.

I. SYSTEMATIC AND ANATOMICAL ACCOUNT.

By C. Forster Cooper, B.A., *Trinity College, Cambridge.*

(With Plate XVIII. and Text-figures 76—89.)

II. NOTE ON MERISTIC VARIATION IN THE GROUP.

By R. C. Punnett, M.A., *Fellow of Gonville and Caius College, and Demonstrator of Comparative Anatomy in the University of Cambridge.*

I. SYSTEMATIC AND ANATOMICAL ACCOUNT (By C. Forster Cooper).

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The following is an account of two species of *Amphioxus* from the Maldive region, one of which, viz. *Heteropleuron maldivense*, is new and related to *H. bassanum*. An account is also given of some larvae, the adults of which are uncertain.

I take this opportunity of thanking Mr Adam Sedgwick for permission to work in his laboratory, and for the great interest he has taken in the work. I am also indebted to Mr J. J. Lister, Major Alcock, Mr R. C. Punnett and Mr Crossland for specimens from other localities in the Indian Ocean. I would also thank Mr A. E. Shipley for the encouragement he has at all times shewn me.

1. ASYMMETRON LUCAYANUM (Andrews). Pl. XVIII. fig. 1.

This species of Cephalochorda is by far the most abundant in the Maldives, occurring roughly in the proportion of 100 to 1 of the only other form found (*Heteropleuron maldivense*). It seems to be identical in almost every particular with the form described by Andrews from the Bahamas[1].

The only point in which the Maldivan and W. Indian forms consistently differ from one another is in their size. The average length of the Maldivan specimens is 23 mm., the extremes being 18 and 30 mm., thus being nearly double the length of the Bahama specimens which Andrews found to average 13 mm. In spite of this difference the average myotome formula for the two forms remains practically the same, the mode in each case being 66 myotomes, *i.e.* 44 from the head to the atriopore, 9 from the atriopore to the anus, and 13 from the anus to the tail.

The most prominent external feature of the species is the long caudal extremity which at once differentiates it from all other known forms of Cephalochorda. There is a narrow rostral fin round the anterior end of the notochord, which projects some 2 mm. beyond the end of the first myotome. This is continued dorsally as a low fin running the whole length of the body to the tip of the caudal extremity. Owing to the taper of the body the fin is rather deeper for the last fifteen myotomes (*i.e.* from about the level of the anus to the caudal extremity). From the last myotome to the tip of the tail it narrows down to a point.

The ventral fin is a continuation of the right metapleural fold, and like the dorsal fin it also broadens out for the last fifteen myotomes, though somewhat deeper than the last named. It bends up suddenly at the last myotome, and becomes the ventral part of the narrow tapering caudal fin. The depth of the dorsal and ventral halves of the latter fin is the same.

In the dorsal fin from about the 17th to the 32nd myotome there are fin-ray spaces containing small blocks of cartilage, the fin rays. These begin anteriorly as small irregular blocks, which gradually increase in size and become more regular, averaging two to a myotome; towards the tail they again decrease in size. There is, however, much variation in different specimens both in the number and size of the fin rays. The ventral fin possesses neither fin rays nor fin-ray spaces.

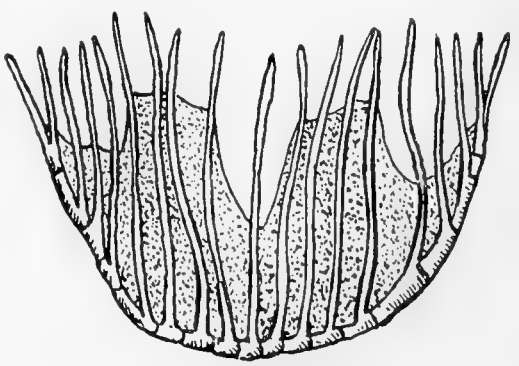

Fig. 76. Buccal cirri of *Asymmetron lucayanum*.

In comparison with *Amphioxus lanceolatus* the general shape of the species is long, thin, and somewhat narrow from side to side. The metapleural folds end short of the buccal hood, and do not in any way connect up with it. The buccal hood is long and shovel-shaped, but not very deep. The buccal cirri number 19, and are divided into two groups on each side of a median unpaired tentacle. The outer group on either side consists of five tentacles joined together by a low membrane, whilst each inner group possesses four tentacles connected by a high membrane which reaches fully three-quarters of the way up the cirri (Fig. 76).

[1] *Stud. Johns Hopkins Biol. Lab.* vol. v.

The tentacles are smooth and without any sensory patches.

The preoral pit is large, and in structure is similar to that of *A. lanceolatus*. The blood vessel running with it breaks up into a glomerulus, in which the vessels are less in number but of a larger sectional area than usually obtains in the European species. In this point there is some variation, certain of the specimens approaching more nearly to the former type, others more to the type as described by Andrews.

The "Räderorgan" is large and well formed. It consists of a large dorsi-lateral arm on each side of the buccal hood, and thin secondary arms with smaller loops in between. The dorsal arm of the left side is longer than that of the right, and connects up with the preoral pit. The whole organ forms a ring of tissue round the base of the buccal hood, the arms being pulled out along its sides.

The mouth and velum underlie the apex of the eleventh myotome. There are eight velar tentacles. The pharynx stretches between the level of the apices of the 10th to the 45th myotome, thus occupying a space a little over half the total length of the body. Both mouth and pharynx as well as the alimentary canal are similar in structure to the corresponding organs in *A. lanceolatus*. The skeletal bars of the gills are normal in general plan, but the synapticulae joining the bars together are only three in number and very slender.

The nervous system presents no great peculiarities, the most noticeable feature being the absence of the olfactory pit, no traces of which could be found. The nerve cord stretches to the tip of the caudal extremity as a very fine thread. Special nerves are given off only in the region of the myotomes. Beyond this point, *i.e.* in the caudal extremity, no nerves arise from the nerve cord.

The excretory system consists solely of patches of epithelium on the floor of the atrial cavity. No trace of nephridia on the gills could be seen, nor could Lankester's brown funnels be traced. Andrews was similarly unable to find these in the Bahama form, so that their non-existence seems certain.

The circulatory system (of which only the main vessels were traced) is similar to that of *A. lanceolatus*.

The gonads are placed on the right epipleur, and are twenty-nine in number, lying from the 14th or 15th to the 43rd or 44th myotomes. The first few gonads are small. They present a gradual increase in size till the centre of the series is reached, after which they again begin to decrease, the last few gonads being of the same size as the first. The period of sexual maturity seems to bear no relation to the size of the animal. Very small specimens were found with well developed gonads (always 29 in number), while some of the largest obtained, measuring 30 mm., had them very little or not at all developed.

2. HETEROPLEURON MALDIVENSE. Pl. XVIII. fig. 2.

This species is by no means common in the Maldive Islands, only four specimens being obtained from Mahlosmadulu Atoll. None were found in the lagoon of the Island of Minikoi, and since Mr Gardiner searched this locality extremely carefully during the months of June, July, August and September without finding either adults or larvae, it may be concluded that it does not occur there.

Heteropleuron maldivense more closely resembles *H. bassanum* (Günther) from Bass' Straits, Australia, than any other species in the genus. It is somewhat similar to this species as figured by Kirkaldy[1] but differs in the shape of the fins, in being of much smaller size, and in some other small particulars.

As there is no account of the anatomy of *H. bassanum*, it is not possible to say whether that species shares the peculiarities of the form here described.

The largest specimen obtained measured 2 cm.[2] (*H. bassanum* averages 4·3 cm., Kirkaldy). The depth is rather large in proportion to the length (Plate XVIII. fig. 2). The dorsal fin is rather narrow posteriorly but becomes broader as it approaches the head, being at its greatest depth about one-sixth of the total depth of the body. It runs forward with only a very slight notch into the moderately-sized rostral fin. It is throughout its length provided with fin-ray spaces and long fin rays closely crowded together. These number between three and four to the myotome, the rays becoming shorter and slightly broader posteriorly.

The rostral fin runs forward for a short way and then bends round the snout, and continues ventrally for a short distance until it finally joins the buccal hood on the left side. The ventral fin has the same depth as the dorsal fin in the corresponding region; it is a continuation of the right metapleural fold, and has single fin-rays and fin-ray spaces, differing in this respect from *H. bassanum* where they are paired.

The caudal fin is lance-shaped and, in comparison with *Amphioxus lanceolatus*, rather narrow. The ventral half is a little deeper than the dorsal. Both the superior and inferior angles are very slight.

The myotome formulae of the four specimens were

	Number of myotomes from		
Total No. of myotomes	Head to atriopore	Atriopore to anus	Anus to tip of tail
73	45	16	12
74	45	16	13
72	46	16	12
75	46	16	13

The average given by Kirkaldy for *H. bassanum* is

75	45	16	14

Anatomy. This species on the whole is similar to *Amphioxus lanceolatus* in its larger features, but presents some minor differences. The preoral pit is rather small compared with that of *A. lanceolatus*, running halfway up the side of the notochord (Fig. 77). Further back it comes to lie high up on the left wall of the buccal hood (Fig. 78). Except at the point where it runs up at the side of the notochord it is very shallow. The blood vessel, which runs above it, is divided at most into two or three vessels, instead of breaking up into a glomerulus as in *A. lanceolatus*.

The "Räderorgan" consists of one median dorsal loop, in the left side of which is placed the preoral pit. Each wing of this loop runs back towards the velum, and then forward again to form the four or more secondary loops on the sides of the buccal hood. The two epithelial tracts join on the base of the velum and complete the ring.

[1] *Q. J. M. S.* vol. xxxvii. (1895).

[2] Table II. in Mr Punnett's account of the Meristic Variation.

The buccal hood is chiefly noticeable for the great extent and thickness of its gelatinous walls, a feature also of the whole front part of the animal.

A section just behind the region, where the rostral fin runs into the apex of the buccal hood, shews the great general development of the gelatinous tissue, when compared with the area occupied by the muscles, &c. (Fig. 79). It will be noticed that in the section figured, the tips of the buccal cirri have been cut through at this level.

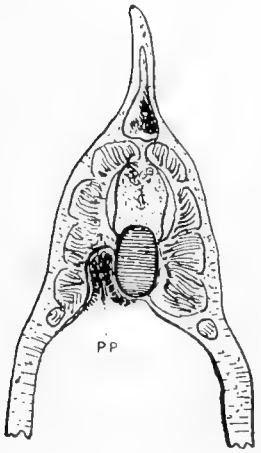

Fig. 77.

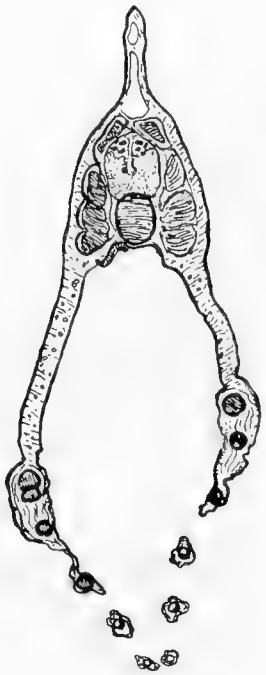

Fig. 78.

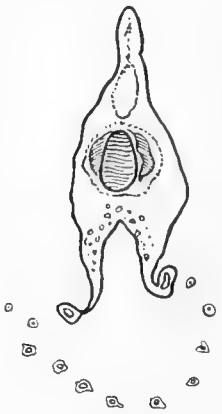

Fig. 79.

Fig. 77. *Heteropleuron maldivense.* Section through the middle of the preoral pit (*P.P.*).

Fig. 78. *Heteropleuron maldivense.* Section through the end of the preoral pit, showing the great development of the hood.

Fig. 79. *Heteropleuron maldivense.* Section through the anterior end of the head immediately behind the rostral fin. The buccal cirri are cut through near their free ends.

The side walls of the hood as they proceed backwards gradually become deeper, and at their lower edges appears the ring of cartilage from which the buccal cirri spring. The hood is of a broad shovel-shape, and the buccal ring thus has a V-shape with a pointed apex and rounded sides. The cirri are 23 in number and are webbed half-way up their extent except the last four on each side, which are small and free. Sections at different levels in front of the velum shew the development of the hood (Figs. 78—80). In the front part of the hood are a number of lymph spaces which traverse the gelatinous substance, and frequently anastomose with one another.

The gill slits in general structure are precisely similar to those of *A. lanceolatus* as are also the branchial skeleton and endostyle. In one specimen a primary bar was found, possessing two skeletal rods (Fig. 81), joined together at their base. They almost directly separated and

ran up side by side, and there was only one division of the coelom as figured. According to Benham this is a fairly common variation in *Amphioxus lanceolatus*[1].

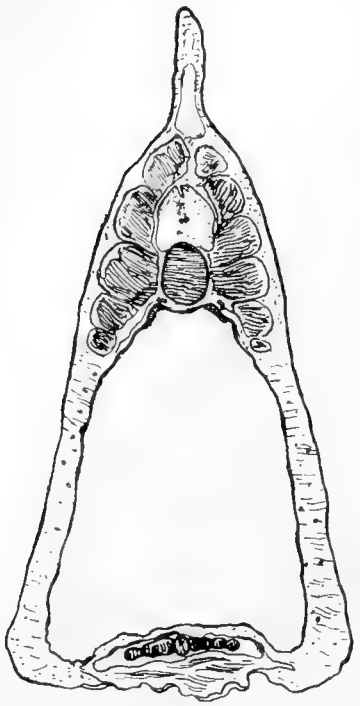

Fig. 80. *Heteropleuron maldivense*. Section just in front of the velum. The origin of the buccal cirri is seen at the bottom.

The alimentary canal from the region of the atriopore stretches through 21 myotomes to the anus. The liver caecum is comparatively short, running through only nine myotomes.

The excretory organs are of the usual type. The epithelial patches on the floor of the atrium are numerous and well-marked. Nephridia on the gills could also as a rule be seen. They have the usual structure as described by Goodrich[2], and their atrial openings were distinctly observed. Lankester's brown funnels do not occur.

The circulatory and nervous systems both conform to the usual type, but in the latter no olfactory pit was found. Only the gross anatomy of these organs could be made out, but as far as the histology was observed, there is no difference between them and the same organs described for *A. lanceolatus*.

Since working out this form I have received a large number of specimens of *H. maldivense* from Mr Crossland, who obtained them at Zanzibar. I have been thus enabled to make a fuller list of measurements, which shew that the size of the animal may be larger than the Maldivan specimens led me to expect, although the average remains about the same. These measurements will be found in Table II. p. 363 of Mr Punnett's "Note on Meristic Variation in the Group." Unfortunately the specimens were not very well preserved. The gonads had in some cases broken away, and in others, marked with a note of interrogation (?), their position was a little doubtful.

To sum up the specific differences between this form and *H. bassanum*. The myotome formula is on average 73 in all, 45 from the head to the atriopore, 16 from the atriopore to the anus, and 12 from the anus to the tail; while the total number in *H. bassanum* is nearly the same, *i.e.* 75, there is a constant difference of two myotomes in the caudal region, *H. bassanum* having 14. The dorsal fin is much deeper than in *bassanum*, the rostral fin is a little smaller and the notch is very much less marked. The preoral cirri number 23 as against 33, and the ventral fin is without the paired fin rays and spaces[3].

Fig. 81. *Heteropleuron maldivense*. Abnormal double gill bar.

3. BRANCHIOSTOMUM PELAGICUM.

Through the kindness of Mr J. J. Lister I have been enabled to examine a specimen of an *Amphioxus*, which was obtained by him in the year 1888 in latitude 21° 16′ S. and longitude 80° 50′ E. *i.e.* in the

[1] *Quart. Journ. Mic. Sci.* 1893, vol. xxxv. Part 1.

[2] *Quart. Journ. Mic. Sci.* 1900, vol. xviii. Part 4.

[3] Dr Benham (*Q. J. M. S.* vol. xliv. p. 276) states that double fin rays do not occur in the ventral fin of *H. bassanum*. Kirkaldy (*loc. cit.*), however, avows that her specimens were in good condition, so that a mistake could hardly have been made. Variation in this respect may occur.

centre of the Indian Ocean about half-way between Madagascar and Australia. The depth at which it was taken cannot be stated with any certainty, as it came up in a dredge which had been working in 800 fathoms. It may thus have been taken on the bottom or enclosed in the net as it was hauled up.

The form on examination proves to be a specimen of *B. pelagicum*, the only other known example of which was taken by the Challenger in 1875 in the open Pacific, and which was described by Günther in the Challenger Report on the pelagic fishes. The specimen considered here was unfortunately in so bad a condition, both externally and internally, that it was impossible to work out its internal anatomy, either by sections or by mounting whole. The Challenger specimen was almost equally bad, so that until fresh and better preserved specimens are obtained, we must remain ignorant of its organisation, which should prove interesting.

FIG. 82. *Branchiostomum pelagicum*. View of the preserved specimen. The branchial region is seen on the under side to the left.

In length the specimen is 21 mm. and it possesses 60 myotomes (the exact number is uncertain owing to decay), while the Challenger specimen had 67 myotomes. The tail fin is broad and lance-shaped, the dorsal and ventral halves being equal (Fig. 82). For the size of the animal it is extraordinarily well-developed, a condition which lends colour to the view that it is a true pelagic organism. A very narrow dorsal fin runs forward from the tail to the head, and an equally narrow ventral fin is present, the precise length of which could not be made out.

The shape of the head is peculiar, being tapered and ending in a pronounced snout. No trace of buccal cirri could be seen either when viewed sideways or when cut into sections. It would indeed seem that the absence of buccal skeleton is a real character, and not due to maceration or loss, none being found in the Challenger specimen. The structure of the branchial region could not be well seen, owing to the bad preservation of the inner parts of my specimen. It appeared however to be peculiarly small in extent, and quite similar to Günther's figure of the Challenger specimen.

4. PELAGIC LARVAE. Pl. XVIII. figs. 3—6.

Although larvae of *Amphioxus* were throughout found to be far from common, about a dozen were taken in the south of Miladumadulu Atoll and in Fadifolu Atoll, during rough and stormy weather in the last fortnight of December, 1899. They were caught at sundry depths from 8 to 20 fathoms. All were secured during the night in the channels leading from the open sea to the atoll lagoons by hanging tow-nets at different depths over the stern of our schooner, in such a manner as to keep them well swung out by the currents, which drive the various forms of the plankton into them.

It cannot be ascertained with any certainty whether the larvae are those of *Asymmetron*, *Heteropleuron* or of some other form the adult of which we did not obtain. There are many reasons, derived from the anatomy of these larvae, why they should not belong to *Asymmetron*, in spite of the fact that this form is present in our collections in the proportion of one hundred or more to one of *H. maldivense* (the only other form found).

The larvae evidently all belong to one and the same species, and, although they do not form a series extending over any considerable period of development, seem to possess some features worth describing. They are all in nearly the same stage, but owing to the unusual nature of their gill clefts, cannot be compared at all closely in point of age with the well-defined stages in the larval history of *Amphioxus lanceolatus* as described by Willey[1].

In shape and external appearance the larvae are not unlike those of *A. lanceolatus* when both are viewed from the side (Pl. XVIII. figs. 3 and 4). There is a moderate-sized dorsal fin extending from the tail to about the level of the end of the pharynx, in front narrowing down to half its previous width, and continuing forward with the same breadth to the front end of the body. The tail fin is lance-shaped, the dorsal and ventral halves being of precisely the same depth. The ventral fin is a continuation of the tail fin, and is similar to, but slightly deeper than, the corresponding part of the dorsal fin. It extends rather further forward than the broad part of the latter, and passes to the right side of the anus.

The youngest larva in the collection measures 5·75 mm. in length and 1·5 mm. in depth (Pl. XVIII. fig. 3), and possesses 60 myotomes. Its external form is as described above, and it has 14 gill slits on the ventral side open to the exterior throughout. A stout notochord of typical structure runs throughout the body from the tip of the snout to the extreme end of the tail.

The central nervous system commences in the second myotome, and extends to the extreme end of the tail, the last part being very slender. The eye spot (Fig. 83) consists of a round mass of black pigment situated on the upper wall of the brain cavity at a little distance from its front end. It is of comparatively large size, and projects into the lumen of the cavity in such a manner as to almost fill it. The eye thus differs a little in position and shape from that found in *A. lanceolatus*, where it is a conical cap of pigment placed on the front end of the brain. The anterior dorsal nerve is very conspicuous, and the spinal nerves are given off in the usual manner. The olfactory pit is placed almost immediately behind the eye spot. Except in being of a rather smaller size it in no way differs from that of *A. lanceolatus*. The presence of this structure proves that these larvae cannot be considered to be the larvae of the Maldive *Asymmetron*, in which it does not occur.

[1] Willey, *Amphioxus and the Ancestry of the Vertebrates.*

The preoral pit is at this stage large and well-formed. At its extreme anterior end it originates as a small knob of tissue projecting into the head cavity (Fig. 84 *PP.*). In this an invagination commences, which rapidly increases in size as it proceeds backwards. On the dorsal side of the pit appears the preoral sense organ (Fig. 85 *P.S.O.*), a ciliated gutter which after proceeding backwards for a short way ends blindly in front of a forward prolongation of the pharyngeal region, the lumen of which opens directly behind the groove (Fig. 86). As shewn in the figure there are two of these blind caeca running up from the pharyngeal region, one dorsal and one ventral to the preoral pit; their walls at the ends are glandular.

The club-shaped gland begins a little in front of the larval mouth opening. It is similar in shape to that described for *A. lanceolatus*, and has the opening in the dorsal arm—by which its cavity is put in connection with that of the pharynx—well-marked. No opening, however, could be found in the lower arm connecting it with the exterior as described by Willey[1]. In this early stage the endostyle is not very far advanced. It shows only as a patch of modified epithelium lying immediately in front of the club-shaped gland.

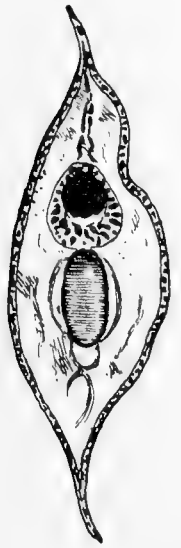

Fig. 83.

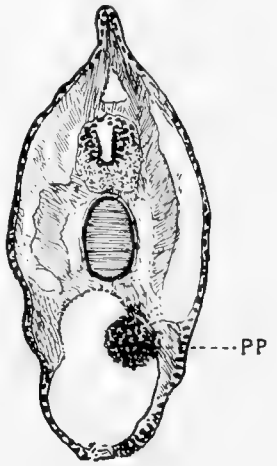

Fig. 84.

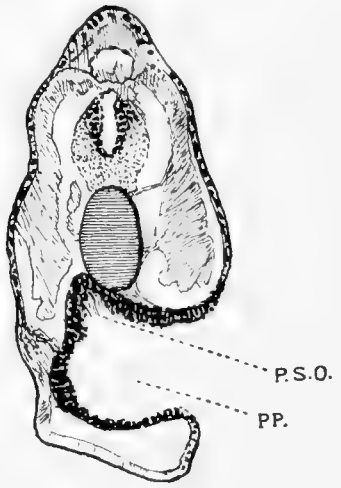

Fig. 85.

Fig. 83. Larva. Transverse section passing through the eye.
Fig. 84. Larva. Section through the anterior part of the preoral pit (*PP*).
Fig. 85. Larva. Section through the middle and largest part of the preoral pit (*PP*). The preoral sense organ (*P.S.O.*) lies dorsally and to the left of the notochord.

The mouth is a small elongated slit lying on the left side about one-third of the way up from the ventral side. The obscure organ termed Hatschek's nephridium lies on the left side just under the notochord and runs into the pharynx.

The first gill slit opens under the mouth and a little to the left of the mid-ventral line (Fig. 87 *G.S.I.*). The next two slits also lie somewhat to the same side gradually approaching the mid-ventral line, in which the rest are placed. The right metapleural fold arises at a more forward level than the left, which starts from the hind corner of the mouth between the second and third gill slits. It rapidly increases in size until it equals its fellow of the right side. Between these folds the gill slits occupy a mid-ventral position.

[1] Willey, *loc. cit.*

On each bridge of tissue between the gill slits the branchial epithelium projects as a mass of large columnar cells with darkly staining nuclei (Fig. 88). Many sections, but by no means all, give an appearance of having the branchial epithelium split into two (Fig. 89)[1]. The latter extends alternately down each side of a slit, so that every slit has the branchial epithelium

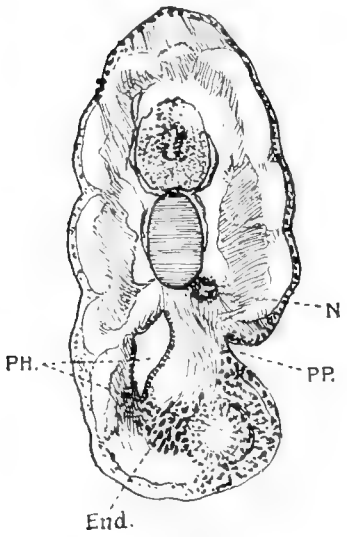

Fig. 86.

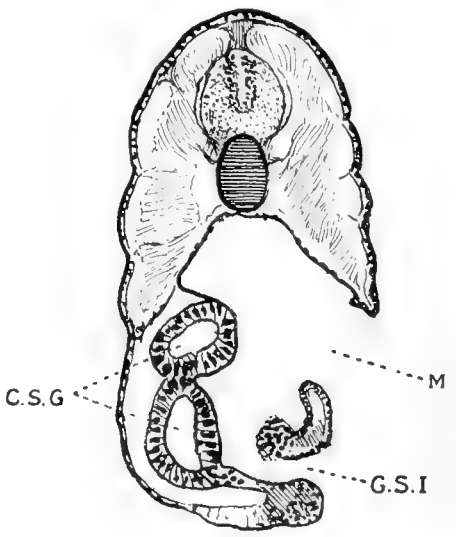

Fig. 87.

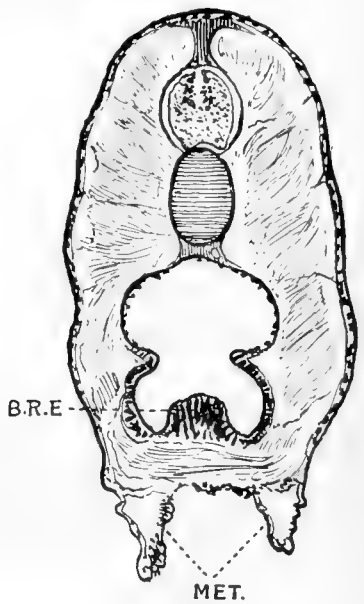

Fig. 88.

Fig. 86. Larva. Section through the extreme posterior end of the preoral pit (*PP.*), showing Hatschek's nephridium (*N*), the commencing formation of the endostyle (*End.*) and the two prolongations of the pharynx (*PH.*).

Fig. 87. Larva. Transverse section passing through the mouth (*M*) and first gill slit (*G.S.I.*). The two arms of the club-shaped gland (*C.S.G.*) are also shown.

Fig. 88. Larva. Section through a part between two gill slits showing the metapleural folds (*MET.*) and the branchial epithelium (*B.R.E.*).

on the opposite side to the one preceding and following it. The meaning of this is not clear, and can only be solved satisfactorily by the examination of later stages.

Springing from the middle of the pharynx are the true hyper-pharyngeal bands. The left-hand band arises immediately behind the mouth, that on the right hand commencing directly behind the club-shaped gland. They both extend through the whole length of the pharynx, and die out at the beginning of the intestine. The latter itself is normal. The glandular patch in the rectum in all these larvae is very noticeable.

Fig. 89. Larva. Section to the right through a gill slit and to the left intermediate to two slits. The left section shows the appearance of splitting found occasionally in the branchial epithelium.

In a later stage (Pl. XVIII. figs. 4 and 5), also having 60 myotomes, various changes are found to have taken place. The endostyle has become fully formed, and has acquired all the essential histological features found in the adult. It still, however, lies in the larval

[1] I am unable to say whether this phenomenon has any real meaning, or is merely due to the combined effects of preservation and section cutting.

position, and has not yet taken up its permanent location on the ventral side of the pharynx, which shews that a certain amount of torsion still has to take place. It now extends over and beyond the club-shaped gland for some distance. The two arms of the latter organ have become histologically differentiated, the upper arm having a large lumen with tall glandular cells, the lower arm being drawn out into a tube with a small lumen and much smaller cells.

The preoral pit now leads right down to the front end of the larval mouth as a narrow gutter, open to the exterior throughout its whole length. The buccal hood has not yet begun to grow out.

In this larva the gill slits numbered 31. As in the younger form all the openings lie in a series one behind another in the mid-ventral line. Plate XVIII. fig. 5 shews the ventral view of this larva. The appearance of the slits in the mid-ventral line is curious, for the reason that the bridges between the openings are very long and narrow. Owing to this they have become much twisted, and their shape somewhat obscured. Their form can, nevertheless, be traced out, and it is seen that they have a somewhat rectangular shape. There is no sign of any crescent-shaped infolding to form a tongue bar. There is absolutely no trace of any secondary gill slits breaking through in the manner usually described—that is, on the right side and above the primary slits. Normally the secondary slits should shew, at their first origin, as six oval thickenings situated on a continuous ridge of tissue, in the right wall of the pharynx above the primary slits, and this should take place when the larva has fourteen primary slits fully formed. As has already been seen the first larva possessed the requisite number of primary slits without signs of the appearance of any secondary ones. Further, in the normal development, the formation of the secondary slits, after they have once started, is very quick, and the number of slits on each side becomes even. A certain number of primary slits close up and a stage with eight on each side is reached.

Indeed, the phenomena found in these larvae cannot be brought into any uniformity with the plan of *A. lanceolatus*. In none of the specimens obtained is there any sign of secondary gills, although possessing from 15 to 31 'primary' slits. It seems impossible that after such a late stage has been reached, the secondary slits should arise by perforation in the usual place, especially now that the metapleural folds have been well formed. What precisely does occur it is impossible to say owing to the lack of the later stages which only could throw light on the subject. For the same reason one cannot say whether any of the slits present close up as do some of the primary slits in the larva of *A. lanceolatus*.

Such evidence as there is, points to some different method of origin of the gills to that which is found in *A. lanceolatus*, the only species in which the full development has been thoroughly observed. There is no reason why all species should have precisely the same way of development, but unfortunately the facts here are hardly sufficient to warrant any deductions as to how the gills arise in the present peculiar form.

The fact that the larvae were taken right away from the grounds where the two Maldivan species of *Cephalochorda* were found, and also that they were taken in heavy weather close to the channels leading from the sea, makes it possible that they may be the larvae of some pelagic form, whose altered mode of life may account for the differences of larval growth mentioned above.

5. DISTRIBUTION AND HABITS OF THE MALDIVAN CEPHALOCHORDA.

1. *Asymmetron lucayanum.*

In the Atoll of Minikoi, which was very thoroughly searched by Mr Gardiner between the months of June and September, many specimens of this form were obtained. Their distribution in the atoll proved to be very local, and although many places at first sight seemed to be suitable they were restricted to practically one spot—viz. the Neru-Magu channel (*vide* Chart, Part I. page 28 of the present work), on the N.W. side of the atoll, which runs in across the sand-flat with a depth of about 2 fathoms. The sides of the channel were of sand and rather steep. The bottom was found to be of rock covered with a few inches of sand and studded with small growths of corals. It was in the shallow sand at the bottom of the channel that the specimens were found.

Very careful search in the sand at the S.W. part of Minikoi lagoon, which is covered by shallow water, revealed only one specimen, and none were found in any other part of the lagoon, except close to the channels from the sea. A few specimens were kept alive for several days in a basin covered with fine silk gauze and sunk in the lagoon. Their dislike to strong light, recorded by Andrews[1], was observed, and Mr Stanley Gardiner also informs me that they were never seen to lie on their sides on the surface of the sand as the European species commonly does.

The distribution in the Maldives is also local and peculiar, specimens often being found in small numbers at unexpected depths and places. A list of the localities and depths is here given.

(1) *Suvadiva Atoll.*

Two specimens were obtained from a hard bottom consisting of rough stony rubble with masses of weed and calcareous algae. 29—30 *f.* (*fathoms*).

(2) *Mahlosmadulu Atoll.*

A few specimens from coarse sand mixed with a little rubble, about 20 *f.*, near Turadu and Duravandu Islands: in the *velu* (lagoon) of the island of Berriamfuri several were secured off the sandy bottom, 3—4 *f.*

(3) *Fadifolu Atoll.*

Several were dredged from a bottom consisting of rough corals, weeds and sponges, in the channel to the north of Naifaro, 15 *f.*, and a few also from a hard bottom with weeds and a little sand, 23 *f.*, near the centre of the lagoon.

(4) *Miladumadulu Atoll.*

Two or three came from a large block of *Porites* which was dredged up, being found in sand which had collected in small quantities in the crevices of the coral, 20 *f.* Several were taken in the sand of the *velus* of the islands of Mafaro and Edufaro, 3 *f.* In Furnadu the shallow sand-flat (2—3 *feet*) between the islands of Furnadu and Farukolu, an area swept by strong tidal currents, yielded a number of specimens.

(5) *Male Atoll.*

In the island of Hulule, where a longer stay than usual was made, a large number of specimens were secured and their distribution was carefully studied. Five only were obtained

[1] *Loc. cit.*

in the *velu* which is a sandy area of considerable size and with an average depth of from 6 to 7 fathoms. Five specimens were also brought up from a depth of 25 fathoms off the west reef of the island, *i.e.* in the main lagoon of the atoll from a bottom of decaying rock and sand.

By far the largest number, however, came from a particular spot at the south end of the *velu*, just to the north of the north-west point of Hulule island. From this end of the island a sand spit runs out for a distance of some 70 yards, the greater part covered at low water. The sand at the end of this spit suddenly dips down into a channel which at low tide never had less than 4 feet of water in it. This channel was about 30 yards across its widest part and ran east and west at right angles to the length of the island. At the further end of the channel was another sand spit of about 50 yards breadth which gradually sank into the *velu*. A current at almost all states of the tide ran up or down the channel, often with considerable force, keeping the sand at the bottom and sides in a continual state of motion, and it was in this sand that *Asymmetron* was found to be most abundant. About two hundred were actually obtained, but any quantity could have been caught if desired. They were taken by wading out into the channel and dipping a sieve into the sand, a dozen or more being often caught in one lot.

It would thus appear that the chief and most favourable habitats are moderately shallow and sandy channels, as in this place, in Furnadu, and in the channel in Minikoi, the three places in which the greatest number were found. In all other places, where there was a greater depth and an absence of current and sand, only a few odd specimens were taken. There were several places visited in which the conditions seemed to be quite suitable for *Amphioxus* but in which no specimens were found. This was notably the case off Goidu in Goifurfehendu Atoll. The reason for this very local distribution is not easy to explain, but it was noticeable that wherever *Asymmetron* was abundant, other sand-living animals were absent or very scarce[1].

The distribution of this species from a larger point of view is interesting. Mr Crossland obtained a few in Zanzibar, but no other specimens are recorded from the Indian Ocean. The only other locality so far recorded is the Bahamas in the West Indies, where they were first obtained by Andrews.

2. *Heteropleuron maldivense.*

The number of specimens found in the Maldives is too small to admit of any deductions as to habitat. Three specimens were found in Mahlosmadulu in coarse sand at a depth of 20 fathoms, and one specimen in a channel into Fadifolu at a depth of 15 fathoms. Mr Crossland, who found a large number of this species in Zanzibar, informs me that they were taken on sandy bottoms at a depth of 7 to 8 fathoms.

The following *Cephalochorda* have now been recorded from the Indian Ocean:—

1. *Amphioxus belcheri* Gray. Madras, 6 fathoms, off "Seven Pagodas, Mahabili," dredged by Major Alcock; and Singapore, several larvae and a few adults. This species also occurs in Prince of Wales Island, Torres Straits and Borneo.

2. *Asymmetron lucayanum* Andrews. Maldive Islands, Minikoi and Zanzibar. The species is found also in the West Indies.

[1] In this connection it may be remarked that *Asymmetron* is a discriminate feeder. It lives on particles of vegetable matter, and does not swallow sand, as do many other sand-living organisms.

3. *Heteropleuron cinghalense* Kirkaldy. Coast of Ceylon.

4. *H. maldivense,* n. sp. Maldive Islands and Zanzibar.

5. *Dolichorhynchus indicus* Willey. "Black Pagoda," off the Orissa coast of India.

6. *Branchiostomum pelagicum* Günther. One specimen each from Indian and Pacific Oceans.

DESCRIPTION OF PLATE XVIII.

Fig. 1. *Asymmetron lucayanum.*

Fig. 2. *Heteropleuron maldivense.*

Fig. 3. Larva with 60 myotomes and 16 gill slits (length 5·75 mm.).

Fig. 4. An older larva with 61 myotomes and 31 gill slits (length 6·5 mm.).

Fig. 5. A ventral view of the above larva shewing the extent of gill slits in the ventral surface. The slits are seen to be of a roughly rectangular shape, the outlines being somewhat obscured by the twisting of the edges.

Fig. 6. Enlarged view of the head of Fig. 3. *e.* eye spot, *b.* brain, *p.p.* preoral pit, *p.s.o.* preoral sense organ, *end.* endostyle, *c.s.g.* club-shaped gland, *g.s.*1. first gill-slit.

Forster Cooper – Cephalochorda.

II. NOTE ON MERISTIC VARIATION IN THE GROUP.

(By R. C. Punnett.)

The Cephalochorda are probably regarded by the majority of zoologists as a form of life which has remained comparatively unchanged during lengthy epochs of time. And although from the nature of the case direct palaeontological evidence is lacking, morphology would seem to support the view that the group is one of great antiquity. Moreover from the paucity of species in existence at the present day and from the similarity of their structure, the zoologist is led to conclude that the group has probably lost the power of extensive further differentiation and is, as it were, on the down grade. In other words it seems natural to regard the existing Cephalochorda as the relics of a great group which flourished in remote geological ages, and which, owing to competition with higher forms, or to environmental changes, or to some other reason, is represented to-day by a few species only. The interesting question then arises to what extent a group, such as the Cephalochorda, which has persisted from remote antiquity, has acquired a fixity of type, and to what extent it may be supposed to have attained to a position of organic stability in which it is incapable of giving origin to new species under altered conditions. If we admit the existence of Natural Selection as a factor in evolution the problem resolves itself into the question whether the variations exhibited are of sufficient magnitude and frequency to allow of the conception of this factor coming into operation.

To consider only the feature of meristic variation, most of the Vertebrata, and especially the lower forms, exhibit considerable variation in the number of segments of which the body is composed. In certain other vertebrates again the number of segments is nearly constant. Especially is this the case among forms which have reached a high pitch of specialization, such as the mackerel[1] among fishes, the Anurous Amphibia, and many birds and mammals. Accompanying this high degree of specialization there would seem to be a loss of plasticity in the meristic series of which the animal is composed. To what extent is this fixity of form to be found among groups of great antiquity as well as among those of high specialization?

Amphioxus would seem to afford an admirable object for consideration in this connection, and with regard to the amount of variation it shews there is some difference of opinion. In his recent work on Nautilus Willey[2] has referred to Amphioxus as "another example of a relatively fixed type which presents little range of variation." On the other hand Kirkaldy[3] has shown that the number of myotomes in all the species known is subject to considerable variation. In this connection it must be mentioned, that although the *range* of variation may be of not inconsiderable extent, the species may yet be a comparatively non-variable one. The number of specimens which group themselves closely round the mean may be very large, whilst those which lie on either side of the mean may be numerically very few. In

[1] Williamson, H. C., *Eighteenth Report of Scottish Fishery Board*, 1899.

[2] Willey, A., *Zoological Results*, Pt. vi. 1902 (p. 811).

[3] Kirkaldy, J. W., *Quart. Journ. Mic. Sci.*, 1895.

TABLE I.

Asymmetron lucayanum (28 specimens).

	Total number of myotomes	Number of myotomes from			Length in mm.
		Head to atriopore	Atriopore to anus	Anus to tip of tail	
	64	43	9	12	20
	65	44	9	12	23
	66	44	9	13	18
	66	44	9	13	20
	66	44	9	13	21
	66	44	9	13	21
	66	44	9	13	22
	66	44	9	13	24
	66	44	9	13	24
	66	44	9	13	25
	66	44	9	13	27
	66	44	9	13	27
	66	44	9	13	30
	66	44	10	12	15
	66	44	10	12	23
	66	44	10	12	25
	66	45	10	11	23
	67	44	10	13	18
	67	44	10	13	23
	67	44	10	13	24
	67	45	9	13	22
	67	46	9	13	28
	68	44	11	13	25
	68	45	10	13	30
	68	45	10	13	25
	69	46	13	10	27
	70	46	12	12	31
	71	45	13	13	21
Mean ...	*66·71*	*44·36*	*9·79*	*12·61*	*23·6*
Mode ...	*66*	*44*	*9*	*13*	—
Range...	*8*	*4*	*5*	*4*	15—30
σ	$\pm 1{\cdot}435$	—	—	—	—
P.E.σ ...	$\pm$ ·129	—	—	—	—

TABLE II. *Heteropleuron maldivense* (45 specimens).

	Total number of myotomes	Head to atriopore	Atriopore to anus	Anus to tip of tail	Number of gonads	Position of gonads	Length in mm.
	70	42	16	12	24	10—34	21·0
	71	44	16	11	30	9—39	23·0
	71	43	16	12	28	9—37	20·0
	71	43	16	12	27	12—39	18·0
	71	43	14	14	27	10—37	26·5
	72	45	15	12	27	10—37	19·5
	72	45	15	12	26	13—39	20·0
	72	44	17	11	26	10—36	26·0
	72	44	16	12	28	10—38	21·0
	72	44	16	12	25	10—35	18·0
	72	43	17	12	broken	away	18·0
	73	46	15	12	28	11—39	21·5
	73	46	15	12	26	10—36	26·0
	73	46	15	12	broken	away	23·5
	73	45	16	12	28	9—37	20·5
	73	45	16	12	28	11—39	20·5
	73	45	16	12	28	11—39	28·0
	73	45	16	12	28	9—37	20·5
	73	45	16	12	28	?	28·5
	73	45	16	12	27	9—36	18·5
	73	45	16	12	27	10—37	18·0
	73	45	16	12	27	10—37	21·0
	73	45	16	12	27	11—38	20·0
	73	45	16	12	27	10—37	22·0
	73	45	16	12	26	11—37	20·0
	73	45	16	12	26	10—36	21·0
	73	45	16	12	25	11—35	27·0
	73	45	16	12	25	11—36	18·5
	73	45	16	12	25	11—36	20·0
	73	45	16	12	25	9—34	27·0
	73	45	16	12	25	10—35	23·0
	73	45	16	12	25	?	20·0
	73	45	16	12	24	10—34	30·0
	73	45	16	12	24	11—35	22·0
	73	45	16	12	24	11—35	21·0
	73	45	16	12	23	12—35	20·0
	73	44	17	12	23	12—35	20·0
	73	44	16	13	26	11—36	23·0
	73	44	16	13	25	10—35	30·0
	73	44	16	13	23	10—33	22·0
	73	42	17	14	25	?	19·0
	74	46	16	12	26	?	20·0
	74	46	15	13	broken	away	26·0
	74	45	16	13	25	11—36	21·5
	76	45	17	14	25	?	24·0
Mean ...	*72·75*	*44·62*	*15·93*	*12·2*	*26·0*	—	*22·1*
Mode ...	*73*	*45*	*16*	*12*	*25*	—	—
Range...	*7*	*5*	*4*	*4*	*8*	—	—
σ	±·879	—	—	—	±1·618	—	—
P.E.σ ...	±·062	—	—	—	± ·119	—	—

such a case the variability of the species as measured by the ordinary methods will be low even though the range of variation is considerable. With the view to throwing some light on the character of such variation among the Branchiostomidae certain measurements were made on 28 specimens of *Asymmetron lucayanum* and 45 specimens of *Heteropleuron maldivense*. The results are given in Tables I. and II. It is to be regretted that a larger amount of material was not examined by Mr C. Forster Cooper, to whom I am indebted for the measurements recorded for *A. lucayanum* and *H. maldivense*.

A glance at the two tables is sufficient to shew that the amount of meristic variation in these two species of Cephalochorda is considerable. And not only the range of variations but also their amount as measured by the standard deviation would appear to be large. Observations on the meristic variability of the various groups of Vertebrata are unfortunately at present very scarce, but such as are available for comparison with the Branchiostomidae are given in the appended table.

TABLE III.[1]

	Locality	σ	P.E.σ	C.V.	Number of specimens
Asymmetron lucayanum.....	Maldive Is.	1·435	±·129	2·15	28
Heteropleuron maldivense	Zanzibar	·879	±·062	1·21	45
Spinax niger (♀ adults).....	Bergen	1·016	±·040	1·55	144
„ „ (♂ „).....	„	1·040	±·054	1·59	84
„ „ (♂ & ♀ embryos)...	„	1·045	±·038	1·61	168
Scyllium canicula.....	Plymouth	1·522	±·092	1·82	53
Pleuronectes platessa	Heligoland	·56	±·014	1·30	341
„ „	Helder	·675	±·023	1·57	200
„ „	Lowestoft	·54	±·019	1·25	170
„ „	Grimsby	·59	±·025	1·37	120
„ „	Aberdeen	·54	±·016	1·25	254
„ „	Solway Firth	·62	±·021	1·44	197
„ „	Baltic	1·02	±·071	2·40	47
Clypea harengus	Dollarts	·773	±·044	1·12	69
„ „	Fair Is.	·667	±·040	1·18	61
„ „	Utsire	1·007	±·066	1·75	52
„ „	Stockholm	·745	±·049	1·34	53
„ „	Zuidersee	·823	±·053	1·49	54
Necturus maculatus.....	N. America	1·942	±·092	4·15	100

[1] The following customary abbreviations have been made use of:—

σ = Standard deviation = $\sqrt{\frac{\Sigma(x^2 \cdot f)}{n}}$,

P.E.σ = Probable error of standard deviation = $\pm 0.6745 \frac{\sigma}{\sqrt{2n}}$,

C.V. = Coefficient of variability = $\frac{\sigma \times 100}{M}$,

where M = the Mean of the number of segments and n = total number of specimens.

For a simple explanation of these formulae *vide* Pearson, *The Grammar of Science*, 1900, p. 384 *et seq.*

The figures given in this table have been calculated from data given in the following papers:—

Pleuronectes. H. M. Kyle, *Eighteenth Annual Report of the Scottish Fishery Board*, 1899.

Clypea. F. Heincke, *Naturgeschichte des Herings*, 1898.

Necturus. H. Bumpus, *Journ. Morph.* vol. xii. 1897.

Spinax and *Scyllium* from unpublished data collected by the writer.

Considering first the case of *Asymmetron*, it will be seen that the variability as measured by the standard deviation (σ) is greater than that found in the Teleosteans and in *Spinax*, being only excelled by that found in *Scyllium* and in *Necturus*. This however is not an altogether satisfactory criterion since it does not take into account the fact that we are dealing with series of segments in which the total number differs greatly in the different groups. The mean number of segments is 66·7 in *Asymmetron*, whilst in *Spinax*[1] it is about 65 and in *Necturus* only 47. This difficulty can to some extent be eliminated by considering the coefficient of variation (C.V.) instead of the standard deviation. When this is done it is found that the value for *Asymmetron* comes out higher than that for all the Elasmobranchs, being only exceeded by the value for *Necturus* and for a local race of Baltic plaice. On the other hand the value for *Heteropleuron* comes out somewhat lower than that for the Elasmobranchs and for most of the plaice and herrings, and very much lower than the value for *Necturus*. When however it is borne in mind that the Vertebrates here dealt with are probably among the most variable species of the group it seems only fair to conclude that the Branchiostomidae form a highly variable group in respect of their meristic segmentation, and that we must give up the idea of their being characterized by fixity of form, at any rate with regard to this feature.

Why then, it may be asked, are the species of Cephalochorda so few in number? The great number of offspring would lead us to suppose that the Struggle for Existence must be severe; the meristic variability of the species hitherto investigated is considerable; and lastly we have no reason for doubting that the Principle of Heredity also holds good in this connection. Moreover many of the species occur in great abundance. We cannot but ask ourselves how it is that, under what seem at first sight such favourable circumstances for its operation, the factor of Natural Selection has not come into play and produced in the group a far greater diversity of form than we meet with. Is it possible that Natural Selection now plays a comparatively unimportant *rôle* in the history of the group as regards the character of meristic segmentation?

In this connection it must not be forgotten that the life of the Branchiostomidae is completed under two entirely different environments. We find at first a pelagic larva produced in enormous numbers, but in which the total number of myotomes is not reached until towards the conclusion of this stage of its existence. It is therefore not easy to see how the high death-rate at this period can affect the ultimate number of segments, *i.e.* whether in this respect it is truly selective. Later we have to deal with an adult so adapted through long ages to living in sand that the constancy and uniformity of its surroundings would seem to reduce the struggle with the environment to a minimum. Again, the greatest variability would hardly be looked for in a species which had been exposed for

[1] In reckoning the number of segments in *Spinax* and in *Scyllium* each pair of "half vertebrae" which characterize the Elasmobranch tail region have been counted as a single segment.

immense periods of time to a selective death-rate in a uniform environment. These considerations coupled with the small number of existing species give us some reason for doubting whether Natural Selection plays much part in determining the number of segments of which these animals are composed.

Supposing then that Natural Selection is not at work on the meristic characters of the Cephalochorda, there may yet be some other factor active in producing modifications. Sexual selection is clearly out of the question and external fertilization seems to preclude the possibility of physiological selection. There yet remains to be considered the factor suggested by Karl Pearson to which he has applied the term Genetic (or Reproductive) Selection. Pearson has suggested that certain characters may be associated with increased fertility. Such characters would tend to assert themselves under a high death-rate, which at the same time need not be selective. To quote his own words—"Those who deny natural selection must, if we can show the existence of genetic selection, still admit that evolution is a reality, for genetic selection produces a continuous change of type which can only be held in check by more or less stringent selection[1]." We have then to enquire whether fertility is really correlated with any other characters,—in this case with the number of somites. And in this connection the Cephalochorda are most favourable objects for study not only from their mode of breeding, but also from the fact that the number of gonads affords us a quick and easy method of estimating the relative fertility in different individuals[2]. Their numerical range of variation is exceedingly large (cf. Table II.) and their variability as measured by the coefficient of variation (C.V. = 6·4) is extremely high compared with that for the total number of segments. That such gonidial variations are to some extent associated with meristic changes in the total number of somites may be seen in the following table for *Heteropleuron maldivense.*

TABLE IV.

Total no. of somites	No. of specimens	Average no. of gonads
70—72	10	26·8
73	29	25·8
74—76	3	25·3

This shews that increase in the number of gonads is associated with a decrease in the number of segments and that the differences are well marked. It may be further shewn that there exists no correlation between the number of gonads and the total length of the specimens (Table V.), or again between the total length and the number of somites in the different specimens.

Hence the correlation shewn in Table IV. is probably direct and not due to gonidial and myotomic variations being both dependent upon some other quality such as length. Unfortunately the data here available are not more than sufficient to warrant these results being regarded as more than a plausible suggestion. Before it would be possible to prove that genetic, and not natural selection, is the factor at work on the meristic segmentation of the

[1] *The Grammar of Science*, 2nd edition, 1900, p. 439.

[2] It is assumed here that the average size of the separate gonads is approximately the same in individuals with a longer and with a shorter series of them. There seems at present no reason against assuming this but direct observations would of course be necessary.

Cephalochorda it would be necessary to establish the correlation between the number of gonads and the total number of somites on a large number of specimens. It would be further necessary to examine the number of somites in a large number at different stages of late larval and early adult life with a view to discovering whether a selective death-rate existed. At the same time it would be interesting to examine the correlation between the number of gonads and the number of somites in the different regions of the animal's body, questions which paucity of data forbids any attempt at answering here.

TABLE V.

	Number of gonads							
	23	24	25	26	27	28	29	30
Average total length (mm.)...	20·7	23·5	22·5	22·3	20·4	22·5	—	23
Number of specimens	3	4	11	7	8	8	—	1

To sum up briefly what has been written above it may be said (1) that the Cephalochorda are with regard to their meristic features a very variable group; (2) that there is reason for doubting that natural selection is now playing much part in modifying them; (3) that genetic selection is probably a factor of considerable importance in modifying the meristic features of the group; and (4) that the conclusions arrived at here are purely tentative but suggest that an ampler study of the group in this connection might be expected to be of considerable interest.

AVES.

By H. Gadow, M.A., Ph.D., F.R.S., and J. Stanley Gardiner, M.A.

INTRODUCTION.

As was to be expected of such small, although numerous, somewhat outlying islands, naturally without much physical variety, the avifauna is composed of few species only, and most of these either marine or waders. None of the birds are peculiar to the islands. The 26 species fall into several categories:—

I. **Permanent residents,** which also breed: *Puffinus, Phaethon, Fregata, Butorides, Ardea, Nettium, Gallinula, Dromas, Anous, Sterna, Corvus,* and possibly *Asio.* The Indian Crow is the only typical land bird of this category. Most of these species have a very wide distribution in the temperate or tropical parts of the Old World.

II. **Winter visitors,** with their natural home on the Asiatic Continent: *Charadrius, Totanus, Falco, Circus, Numenius, Eudynamis, Asio,* and *Hirundo urbica.* Specimens of the full snipe were seen to remain on certain of the islands throughout the year, but it would be very abnormal, if it did really breed on any of them.

III. **Accidental visitors** from the nearest land, e.g. India and Ceylon: *Hirundo rustica, Herodias garzetta,* and the Ceylonese Parakeet, *Palaeornis calthropae.* The latter is a rather unexpected visitor, hitherto not recorded so far from its home.

Remarkable, and not easily accounted for, is the total absence of Finches, Starlings, and above all, of Pigeons.

The notes on the different species have been for the most part copied from the original diary. Unless the species is mentioned in "The Fauna of British Indian Birds," by W. T. Blanford and Eugene W. Oates, a reference is given to the British Museum Catalogue. The species marked with a star have been observed only, but we do not think that there can be in any case any doubt as to the species, which were generally described, when seen, in Mr Stanley Gardiner's diary.

A remarkable feature at Hulule was the daily retirement of all birds from about 11 a.m. to 3 p.m. The heron and tropic-bird were then at rest in the coconut trees, and even the ubiquitous crows retired into the low bushes near the village. The terns about noon might commonly be seen to have settled on the north point of the island, while the waders had long before retreated to the shores of some one of the uninhabited islands.

SYSTEMATIC LIST.

1. *Puffinus persicus.* Fauna, Brit. Ind., IV, p. 356.

In every one of the three adult specimens brought home the primary quill is slightly (about 0·1 inch) longer than the second. The longest of the under-tail coverts are sooty. In one specimen the shorter under-tail coverts are paler, with whitish outer webs; white towards the base of both webs. In the two other specimens these coverts are dark, sooty, just visibly tipped with white.

"This bird was found breeding in great numbers in Difuri and Olivelifuri to the east of Fadifolu Atoll. The single white egg was placed at the slightly hollowed-out end of a hole, about a yard deep, either in the sand or under a coconut or other tree. The burrows appeared to be those of a large crab (*Cardiosoma carnifex*), that had been by some means dispossessed. On Dec. 29, 1899, we opened several of the holes, in some finding crabs and in others eggs or young birds. The latter are regularly taken and eaten by the natives of the atoll."

2. *Phaëthon lepturus.* Ogilvie-Grant, Cat. B. M., XXVI, p. 453 (1898). Adult, nestling and egg.

The above specimens of this Tropic-bird were taken at Hebaridu, South Mahlosmadulu Atoll, on Nov. 24, 1899. "In a hollowed-out branch of a Tulip-tree (*Hernandea peltata*) I caught three of these birds sitting. The branch sloped upwards slightly, and the nests were situated above, but within sight of one another. The nests were made of the decaying wood with sticks, pieces of grass and coconut leaves. The top bird was a female with one nestling, the middle bird a male with an empty nest and the lower bird a female with 1 egg. The male sat just as tightly as the females and indeed fought harder than they did when I removed him. The females I allowed to go free, when they at once proceeded to a Pandanus tree, up which they climbed, so as to get a jump off for flight. My boys, curiously enough, brought down from a neighbouring tree 2 females and 1 male, both the former with young."

The species was seen in nearly every atoll in the group, even in Addu. At Hulule, Male Atoll, it circled overhead daily, filling the air with its shrill shrieks.

*3. *Fregata ariel.* Fauna Brit. Ind., IV, p. 338. The Smaller Frigate-bird.

Solitary birds of this species were frequently seen in the Maldives. Its only breeding-place seemed to be at Olugeri at the extreme south of Mahlosmadulu. This is an uninhabited island covered with large timber trees (*Calophyllum inophyllum* and *Terminalia catappa*), in the tops of which the nests are placed. The appearance is not unlike an immense rookery, allowing for the difference in the more massive mode of growth of the above trees as compared with English timber. On Nov. 13, 1899, during our stay at Turadu, a neighbouring island, the people and our crew made a night expedition to the rookery, and brought back about 40 young birds nearly fledged. No eggs were found.

4. *Butorides javanica.* Fauna Brit. Ind., IV, p. 395.

The Little Green Heron is found in every island of the Maldives, where there is dense jungle, being observed in the Mahlos, Miladumadulu, Male, Nilandu, Suvadiva and Addu Atolls.

It especially frequents the mangroves at the edges of swamps, and breeds in the same places. It is never seen on the shores nor in the open, unless flushed.

5. *Ardea cinerea.* Fauna Brit. Ind., IV, p. 382.

The Common Grey Heron is found in Minikoi and in all parts of the Maldive Group. Solitary birds frequent the shore, the boulder zone and those parts of the reef which are exposed at low tide. The species feeds largely on the beach crabs (*Ocypode*), with the shells of which it strews the shores. The bird is especially numerous in the west of North Mahlosmadulu, roosting in the south island of Bodu-faro and in Limbo-Kandu. The nest is placed in the crown of a tall coconut tree. One bird reared its young during my visit to Minikoi on Wiringili island (July and August, 1899).

*6. *Herodias garzetta.* Fauna Brit. Ind., IV, p. 387. The Little Egret.

A single bird appeared in the clearing round the lighthouse at Minikoi in July, 1899, and I saw a second in Hedufuri, S. Mahlosmadulu. There were also two tamed birds in Huludu, Addu Atoll. The presence of one of these birds in any island—their colour, white, being beloved of Mahommed—is considered a lucky sign. Neither my companion nor I hence cared to shoot a specimen.

*7. *Nettium crecca.* Fauna Brit. Ind., IV, p. 443. The Common Teal.

A pair of these birds were seen in a small pool at Maduwari, S. Mahlosmadulu. Several were also observed in Miladumadulu, seeming to frequent a series of large fresh-water lakes in the islands of the east rim between Furnadu and Landu. In Kendikolu, one of these islands, Mr Forster Cooper found two old birds and three young ones.

8. *Falco tinnunculus.* Fauna Brit. Ind., III, p. 428.

The two female specimens of Kestrel brought home are rather long winged.

Wing,	9·8	inches and	10·5	inches.	Blandford gives	9·5	inches.
Tail,	6·5	„ „	7·3	„	„ „	6·75	„
Tarsus,	1·5	„ „	1·6	„	„ „	1·5	„

9. *Circus macrurus.* Fauna Brit. Ind., III, p. 381. The Pale Harrier.

10. *Circus cineraceus.* Fauna Brit. Ind., III, p. 383. Montagu's Harrier.

The Kestrel and these two Harriers were all very common from October to February in the northern part of the Maldives. None, however, were seen in Addu, Suvadiva or elsewhere in April. Although only a few specimens of the Harriers were preserved, a very large number were shot by request of the natives, whose chickens are often killed and carried off by them.

11. *Gallinula* (*Amaurornis*) *phoenicura.* Fauna Brit. Ind., IV, p. 173. Native Maldivian name "kambili." The White-breasted Water-hen.

This Rail is found sparingly right through the whole Maldive Archipelago, being observed even in Midu and Maradu Islands in Addu Atoll. A few inhabit the jungle of the south end of Minikoi, and at the end of July, 1899, a young bird was taken from the nest, a mere hollow in the ground among some dry rushes. In Kendikolu, Miladumadulu Atoll, the species is very numerous in the mangrove swamps around some fresh-water pools, and in

Hulule two or three birds used daily to visit our midden. In some islands the natives regularly catch them by means of nooses, laid down in their runs.

*12. *Charadrius fulvus.* Fauna Brit. Ind., IV, p. 234.

The Eastern Golden Plover is often tamed both in the Maldives and Laccadives. There were two in Minikoi and several in Male and the various islands of Addu Atoll. In addition a small flock was seen wild in Bodu Mandu, Miladumadulu Atoll.

13. *Numenius phaeopus.* Fauna Brit. Ind., IV, p. 253.

The Whimbrel is a regular visitor to the Maldives from November to March, when it proceeds northwards again. Three or four birds are occasionally seen together on the wing, but single specimens are more often found and are then exceedingly shy of approach. The species was frequently noticed in Mahlosmadulu and Miladumadulu, and a single bird frequented the reefs of Hulule, Male Atoll.

14. *Gallinago coelestis.* Fauna Brit. Ind., IV, p. 286.

The Full Snipe was extremely numerous in April, 1900, on the mud-flats of Addu Atoll at low tide. At high tide it frequented in particular a large rush-covered swamp extending along the middle of the north-eastern island between the villages of Huludu and Midu. The bird is said to be plentiful in this Atoll at all seasons of the year. It therefore must breed there, and indeed its nest—on tussocks of the rush—and eggs appeared on enquiry to be well-known to the natives. The species may have been seen, but it was never identified nor shot in any other part of the Maldives.

15. *Totanus hypoleucus.* Fauna Brit. Ind., IV, p. 260.

The Common Sandpiper was observed at Minikoi in August and frequently in the Maldives between October and April. It generally occurs in single pairs or small flocks—seldom more than six in number frequenting the rocky shores of the islands.

16. *Dromas ardeola.* Fauna Brit. Ind., IV, p. 208.

The Crab-Plover was observed only in the middle of December, 1899, in Miladumadulu Atoll. It was especially numerous round Furnadu, affecting a series of sand-banks along the reefs. Several small flocks of four to about a dozen were seen, flying from place to place and feeding, where the waves lap against the beaches, on small Ocypodes and other Crustacea. The Maldivians say that the species does not breed in their Group, and indeed—assuming that the accounts of its nesting are correct—as the sand is all very loose, it is difficult to see where it could do so.

The species ranges from Madagascar and East Africa to Ceylon, the Andamans and Nicobars; it has also been recorded on the Laccadives.

17. *Anous tenuirostris = leucocapillus* Gould. Fauna Brit. Ind., IV, p. 326.

The White-headed Noddy is nowhere common, but found throughout the whole of the Maldives. It breeds in S. Mahlosmadulu and other atolls on the Screw Pine trees (Pandanus).

One of the adult specimens, obtained on April 14, 1900, was moulting. An adult female and nestling were taken from a Pandanus tree on Mabaru, S. Mahlosmadulu by Mr Forster Cooper on Nov. 26, 1899.

18. *Sterna fuliginosa.* Fauna Brit. Ind., IV, p. 324. The Sooty Tern.

One immature specimen from Minikoi; most of the feathers above have whitish or pale brownish tips. Recorded by Hume from the Laccadives.

19. *Sterna melanauchen.* Fauna Brit. Ind., IV, p. 322. The Black-naped Tern.

The two adult specimens have the following measurements, which do not seem to agree exactly with previous records: culmen 1·4 and 1·6 inches; wing 7·9 and 8·5 inches; tarsus 0·6 and 0·65 inch.

The Terns preceding and following this species are both abundant in the Maldives, but this is by far the commonest, sometimes large flocks almost completely covering the sand-banks which are exposed at low tide. All three species were seen from October to January, but not subsequent to the latter month, seeming almost to leave with the full setting-in of the north-east monsoon.

20. *Sterna bernsteini.* Saunders, Cat. B. M., XXXV, p. 96 (1896).

21. *Eudynamis honorata.* Fauna Brit. Ind., III, p. 229. *The Indian Koel.* Maldivan "kooveli."

This Cuckoo—the male called by the natives *kalu* (black) *kooveli* and the female *hudu* (light) *kooveli*—was constantly seen in the months of November and December in Mahlosmadulu, Miladumadulu and Fadifolu. A pair frequented the Banyan trees in Hulule, Male Atoll, in January but disappeared at the beginning of February. The bird was not seen in April in Addu or Suvadiva Atolls.

The species in the Maldives keeps to the densest part of the jungle, frequenting the Breadfruit, Banyan and *Calophyllum* trees. Males were much less numerous than females, three or four of the latter being seen to one of the former. The natives of Mahlosmadulu, even in the Maldives noteably unobservant, know the difference between the males and females, and state that a few breed every year in their islands.

Concerning outlying islands this cuckoo has been found also on the South Andamans, on Little Coco Island, and by H. O. Forbes on the Laccadives in the month of February.

*22. *Palaeornis calthropae.* Fauna Brit. Ind., III, p. 256. Layard's Ceylon Parakeet.

A pair of green parakeets a little bigger than a thrush and of a brilliant green colour all over—were on two occasions at the end of January seen at Hulule, Male Atoll. The birds were among the *funa* trees (*Calophyllum inophyllum*), the nuts of which they seemed to be eating. They were probably driven down by the heavy north-easterly winds, at that time experienced in the Maldives.

23. *Asio accipitrinus.* Fauna Brit. Ind., III, p. 271.

A dead specimen of the Short-eared Owl was found in Furudu, Goifurfehendu Atoll, in October and one was shot in Kendikolu, Miladumadulu Atoll, in December. In January and February two or three were to be seen nightly flying over the low bushy land to the north and east of Hulule, Male Atoll. In April the bird was also seen in Suvadiva and Addu Atolls, and at Male Island.

*24. *Hirundo rustica.* Fauna Brit. Ind., II, p. 277.

Several swallows appeared at Minikoi on Sept. 1, but were not seen subsequent to Sept. 4.

*25. *Hirundo urbica.* Fauna Brit. Ind., II, p. 269.

At the end of January a number of Martins arrived at Hulule, and were to be seen daily from about 4 to 6 p.m., circling over the village. During the whole of February also they were observed over the neighbouring island of Male.

26. *Corvus splendens.* Fauna Brit. Ind., I, p. 20. Maldivan "kalu."

The Indian Crow is found in every inhabited island of the Maldives, but is curiously enough absent from Minikoi. The birds are regular inhabitants and scavengers of the villages, glutting themselves in the fishing season with the guts of the bonito. The natives state that they are permanent residents and breed in the islands. Their breeding season must then be between May and September, *i.e.* in the south-west monsoon, as we never saw any trace of nesting in the other months.

THE EARTHWORMS OF THE MALDIVE AND LACCADIVE ISLANDS.

By Frank E. Beddard, F.R.S., *Vice-Secretary of the Zoological Society of London.*

I believe that no collection of earthworms from these islands has ever been reported upon. I am therefore particularly obliged to Mr J. Stanley Gardiner and his colleagues for the considerable collection of these Annelids which they have made with so much care and have been so good as to place in my hands for study and description.

I have no general conclusions of importance to urge as a result of my examination of this collection, save to emphasise the belief, now becoming firmly founded, that these Annelids on account of the practical impossibility of their unassisted migration over tracts of sea will serve as the very best test of whether a given isolated island is truly oceanic or not. This is however subject, as Dr Michaelsen has pointed out, to one exception and that is the genus *Pontodrilus*. This genus, of which several species are now known, as a rule but not always lives upon the sea-shore in decaying sea-weed and such like *débris*; the nature of its habitat therefore precludes any impossibility of chance migration from the shores of one tract of land to the shores of another.

The present collection contains one undoubtedly new species of this nearly ubiquitous genus. And that is the only new form which I have found among the three species of earthworms upon which I report here. The rest are precisely what might be expected from the proximity of the islands to Ceylon and India; the two species are both of them common Oriental species. It is very probably in part the abundance of *Megascolex mauritii* which has led to its so wide range. But the relations between the ease with which various species can be transported to regions of quite a different climate and flourish there and other conditions have not yet been guessed at. The material in the way of fact is at present hardly sufficiently large.

1. *Pontodrilus laccadivensis* n. sp.

I have examined a large number of examples of this species which I at first took to be Dr Michaelsen's *P. matshusimensis, var. chathamianus*[1] on account of the nearly similar disposition of the anterior genital papillae. There is, however, not an exact correspondence in the position and number of them, while other features in the organisation of this *Pontodrilus* from the Laccadives forbid its identification with Michaelsen's variety. There is no other species to which it presents so close a likeness in external characters.

It is a long, slender species like other *Pontodrilus*, of 90 to 110 mm. in length. The prostomium impinges slightly upon the buccal ring. The clitellum occupies segments xiii—xvii, and there is always a ventral band left devoid of modification. I have studied 13 fully mature examples of this species, all of which show some of the anticlitellian papillae which distinguish this species from all other *Pontodrilus* except Michaelsen's variety. These papillae

[1] *Zool. Jahrb. Syst. Abth.* xii. p. 220.

are not, however, equally or similarly developed in all. In seven examples there are two papillae plainly visible; one lies between segments XII/XIII and is, as a rule, much more conspicuous by reason of its convexity than the second papilla, which is *not* intersegmental in its position. It lies on XIV, though near to the anterior margin of that segment and not between XIII/XIV. In six individuals one or other of these papillae was missing. In the last individual the two papillae were between XI/XII and XII/XIII, and both were of the same character. I may observe that the papilla upon segment XIV and that upon segments XII/XIII occasionally showed considerable traces of being double. In no individual did I find a papilla between XIV/XV such as is mentioned by Michaelsen in his description of *P. matsushimensis var. chathamianus*. In addition to these papillae there are, as Michaelsen has pointed out, others situated more anteriorly still.

In four individuals there were very evident long, dumb-bell shaped thickenings of the integument occupying the intersegmentary regions VII/VIII and VIII/IX. Each is median and unpaired and ends at the conspicuous orifices of the spermathecae. They do not obliterate the intersegmental grooves. The orifices of the spermathecae correspond to the outer section of the ventral couple. The male pores lie in an area which appears to me to be exactly like that figured by Izuka for *Pontodrilus matsushimensis*[1]. It is quite conspicuous even in immature individuals. So also is the one genital papilla which follows the male pores. This is as usual on the intersegment XIX/XX and is generally hollowed out and sucker-like. It is even apt to be squarish in outline.

As to the internal characters of this species the chief facts which I have observed are the following: the specially thickened mesenteries are those which divide segments VI/XIII, and they are all cup-shaped, with the concavity, of course, anterior. The gizzard is feeble, but still recognisable; it lies in the VIIth segment. In the XIIIth segment are a pair of conspicuous and presumably contractile hearts. The nephridia begin in segment XIII.

The racemose sperm sacs lie in segments XI and XII. The spermathecae are plainly divisible into a thin walled sac and a shorter thick walled duct. The tubular diverticulum is fully as long as the pouch. The spermiducal glands have a long, curved, muscular duct of glittering appearance, fully 2 mm. long.

Locality: Minikoï, Laccadive Islands; and Goidu, Goifurfehendu[2] and Hedufuri, S. Mahlos[3], both Maldive Islands.

2. *Megascolex mauritii* (Kimb.).

Lampito mauritii Kinberg Öfv. Sv. Ak. Förh. 1867, p. 103.

This very common and widely spread Oriental species is abundant in the collection.

Localities: Kumfinadu and Madu, both S. Mahlos; Maungudu, Miladumadulu; Goidu, Goifurfehendu; Hulule, Male; Maradu, Addu, all Maldive Islands; and Minikoi, Laccadive Islands.

3. *Perionyx*, sp.

A number of examples of this characteristic Oriental genus were collected, but they were quite immature and I am therefore unable to identify the species.

Localities: Madu, S. Mahlos; Fainu, N. Mahlos; and Maradu, Addu, all Maldive Islands.

[1] *Annot. Zool. Japon.* II. i. p. 21, Tab. 2, fig. 1.

[2] A single specimen from this locality may possibly not belong to the same species; it was immature, but I refer it to *P. laccadivensis* on account of the exact similarity of the spermiducal glands and of its general appearance to that species.

[3] The same observation applies to a few specimens from this locality. The spermathecae however were well developed and had each a long diverticulum, thus increasing the likeness to the examples from the Laccadives.

THE MALDIVE AND LACCADIVE GROUPS, WITH NOTES ON OTHER CORAL FORMATIONS IN THE INDIAN OCEAN (*concluded*).

By J. Stanley Gardiner, M.A., *Fellow of Gonville and Caius College, and late Balfour Student in the University of Cambridge.*

(With Plates XIX—XXI. and Text-Figs. 90—109.)

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APPENDIX. B.

In the following account the condition of each bank is summarised at the beginning of its section. A detailed account of the parts visited follows in smaller type.

I. Goifurfehendu[1] (Fig. 90).

This atoll is one of the most perfect in the group, having only a single passage with 4—6 fathoms of water to the south. Its situation, on the west side of the wide channel that separates the long double line of banks into two parts (Pl. IX.), causes it to be more exposed and subject to more purely oceanic conditions than any other of the more perfect atolls of small size except Addu. It is yet to some extent protected by the east horn of S. Mahlosmadulu, which seemed to me to divert the currents of the N.E. monsoon more or less away from its northern reef. The S.W. monsoon naturally impinges mainly on its south and west sides, leaving the N.E. part little affected. Perhaps it is owing to these causes that the greater part of the land lies on the northern rim of the atoll.

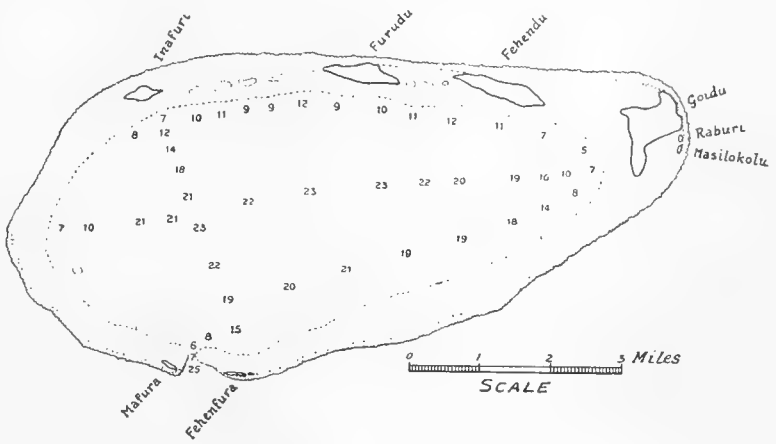


Fig. 90. Goifurfehendu Atoll.

There is little to show the past history of Goifurfehendu, but a line of coral rock and two islets to the west of Goidu, together with a series of masses on either side of the passage, prove elevation (Figs. 92—3). A certain number of coral pinnacles, running from Goidu westwards in the boulder zone of the reef as far as the passage, indicates that the elevated land once probably extended along the whole south side of the atoll.

The comparatively recent connection of Fehendu and Furudu is certain, and there are again sand banks forming along the whole northern reef. There is no indication that the northern islands owe their origin to elevation in any way. Indeed, it is more than probable that their formation was in the first place due to the piling up of sand by the waves and wind from off the sand flats that fringe the lagoon.

The lagoon is increasing in size at the expense of its encircling reef. It is singularly open, no trace of coral growth, except near the encircling reefs, nor of shoaling being anywhere found. Its bottom is everywhere covered by a muddy, calcareous sand, coarser near the reefs

[1] Mr Forster Cooper and I spent 10 days in this atoll at the beginning of November, 1899. In addition to visiting all the islands and examining the reefs in every situation, we put down a number of dredgings in the lagoon, which however only served to show the great poverty of both free and fixed animal life, save in the immediate proximity of the encircling reefs or of shoals.

and finer towards the centre of the lagoon, formed mainly of coral fragments, but containing also *Halimeda* remains, bottom-living Foraminifera and a few shells of pelagic animals.

Goidu island lies with its eastern side right on the reef-flat, which off it approximates to that of the east side of Minikoi near Mou-Rambu Point (p. 40), being about 50 yards in breadth from the base of the beach with two ill-defined terraces and studded all over with pinnacles and masses of the elevated coral rock. The beach behind is mainly formed of the solid rock, slightly overlaid with loose stones. It is the outer edge of a rocky belt of land, about 70 yards broad by 4—5 feet above the high tide level, which behind merges into the sand forming the rest of the island. The latter area averages $2\frac{1}{2}$ feet above the high tide limit, but a small mangrove swamp exists behind the northern half of the rocky belt. To the north the latter continues out into a point on the boulder zone, and to the south masses of rock on and inside the same zone show that it was once joined up to two rocky islets, **Raburi** and **Masilokolu**. The rocky land, wherever exposed, shows some slight loss, but the latter is more marked in two bays that have formed to the south and north of Goidu, in which there is some fallen timber. These are separated from the lagoon by two very prominent points of the land, on which the sand from the two bays appears to be piled up so that they are, if anything, growing out along the encircling reef of the atoll. The west or lagoon side of the island has a broad sandy beach with no rock, and exhibits no marked change of any sort.

Fehendu extends almost east and west for about $1\frac{1}{2}$ miles. It is formed entirely of sand, and lies to the west about 100 yards and to the east about 400 yards behind the boulder zone. To the north or seaward side the whole shore is studded with lines of beach sandstone which

Fig. 91. The reef to the N.E. of Furudu at half tide, looking seaward. The washing away of the land is well seen in the fallen coconut tree and the conspicuous line of beach sandstone extending out from the land.

generally are separated by areas of loose sand. Often, however, the lower terraces lie on the sand-flat quite beyond the slope of the beach, in one place eight separate terraces having been found. The west end of the island is pointed, and the loss in this half is shown on both sides by a cliff with fallen bushes at the top of each beach. At the extreme west point a sand-spit stretches out for 50 yards with a number of sandstone masses along its seaward side and off its

end, showing that the island must have at one time extended considerably further along the reef. Sandstone terraces also occur along the whole of the lagoon beach, but in its eastern half the loss is local, and there is little change at the present time going on at this end of the island. The remains of sandstone lines on the sand-flat at the base of the beach show, however, that in recent years the island extended at the least 25 yards further out on its sand-flat towards the lagoon.

Furudu also is formed entirely of sand, and its north shore lies 80—100 yards behind the boulder zone of the reef. Its beach is coated with sandstone, but the sea has recently broken through this at the east end of the island and washed away much of the sand, so that the trend of the island causes it to be further distant from the reef in this part. The sandstone, nevertheless, still remains as a line of masses, about 90 yards behind the boulder zone. These continue right across to the west end of Fehendu, thus proving the former continuity of the two islands. Further lagoonwards again a series of four sand banks connects the islands, but whether this area was ever covered by the land it is impossible to say. The sand banks and the points of the islands are certainly now growing by the piling up of sand from the lagoon by the winds and waves. Along the south side of the island there is at present little or no change taking place, but a few sandstone masses on the flat off the beach prove that the island formerly extended out further towards the lagoon.

Perhaps the most noticeable point about Furudu lies in its beach sandstone to the north being but little terraced. It presents in many places a cliff of 2 or 3 feet to the sea with one solid mass of rock on the beach behind. This formation is probably due to the protected situation of the island behind the boulder zone and to its situation to the north of the atoll. The sea has not overtopped the sandstone, and its removal must be by the undermining action of the water, both erosion and solution, just as a pinnacle of coral rock is worn away. At the same time the formation on the beach above up to the high tide level must go on, and the sandstone thus necessarily affords very considerable protection to the land.

Fig. 92. Fehenfura from the lagoon.

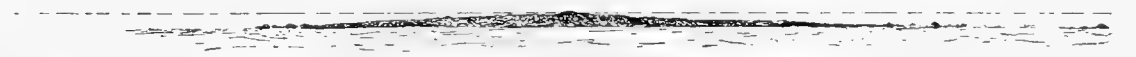


Fig. 93. Mafura from seaward.

Inafuri resembles Furudu—to which it is connected by five large sand banks on the reef as well as by a few sandstone rocks—in its situation in respect to the boulder zone and in being formed of sand alone. It has a terraced sandstone formation on its shores, but this is nowhere extensive and towards the lagoon almost non-existent.

The only other approach to land in the atoll is in two water-swept masses, exposed for 6—8 feet at low tide and stretching for some distance along the reefs on either side of the passage into the lagoon. They are formed of coral rock, and lie on the boulder zone, along which isolated masses continue for some distance at either end. They represent the same line of rock that occurs to the east of Goidu, and, if clothed with vegetation, would be not dissimilar to Raburi and Masilokolu. The natives have definite names for them, that to the east of the passage being called **Fehenfura** and that to the west **Mafura**, and maintain that they were once inhabited land, though they could not produce any evidence in support of their contention.

The reef-flat around the whole atoll is quite similar to that on the west of Minikoi, where no land exists (p. 43). Behind it the boulder zone everywhere continues, consisting mostly of loose masses, but with here and there to the south larger rocks, apparently due to elevation. The whole encircling reef to the south is nowhere more than 500 to 600 yards broad, and to the west appears scarcely any wider. The outer contour of the atoll is almost as drawn in the Admiralty Chart so that, as the encircling reef is charted as very much broader, the lagoon would appear to have enlarged somewhat since the survey. The encircling reef is fringed against the lagoon with living corals, and its edge, like such shoals as arise separately in the lagoon, falls precipitously or even overhangs its base.

II. South Mahlosmadulu (Fig. 94).

Our visit to this bank was made under the most unfavourable circumstances in that

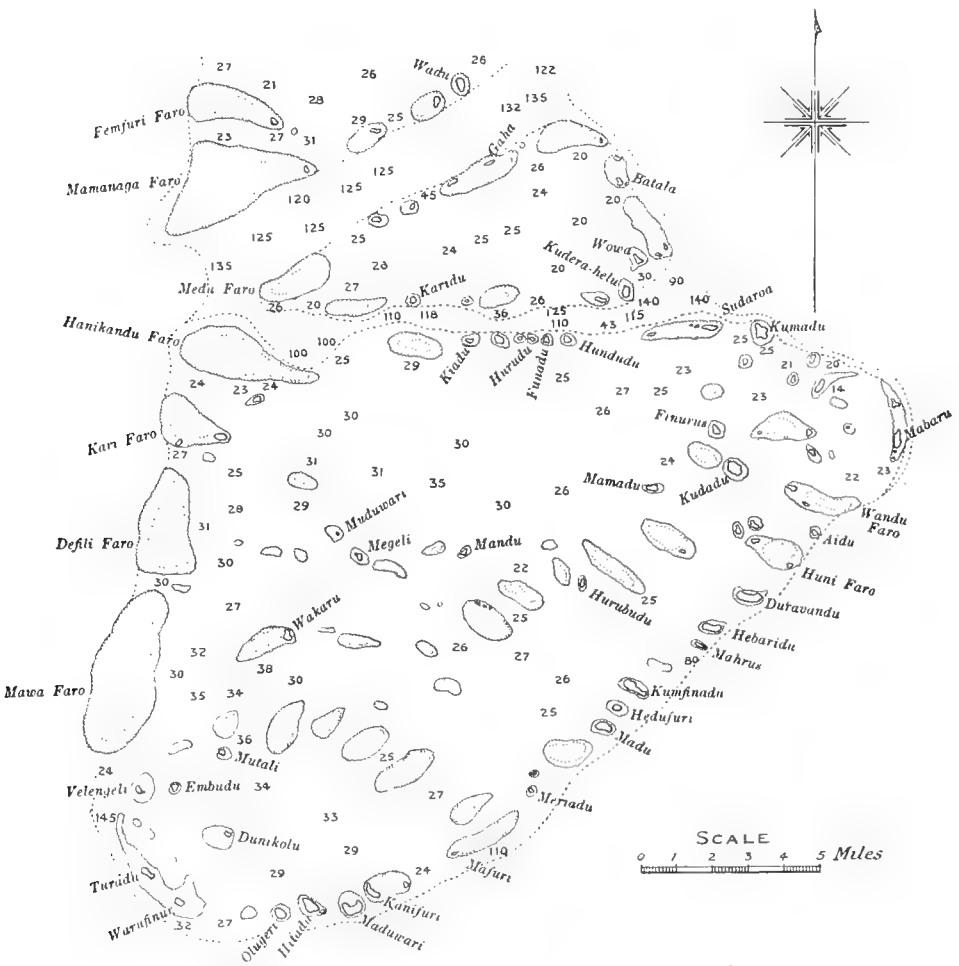


Fig. 94. South Mahlosmadulu Bank (*chiefly from the Admiralty Chart*).

the weather was dead calm during the three weeks we spent in it, and our crew were not as yet accustomed to the working of a schooner. As it was, we commandeered fishing boats

to tow us from place to place, and used the same for visiting the reefs and dredging. Our work, however, had to be largely restricted to a belt 5—6 miles in width along the broad south and south-east part of the bank. The season (Nov. 11—30) was that at the commencement of the N. E. monsoon, when the currents gradually change completely round from about W. S. W. to E. N. E. The current of the N. E. monsoon sweeps through the Kardiva channel with great force, but passes mainly to the south of Goifurfehendu. S. Mahlos is rather affected by that across Fadifolu, and between that atoll and the Miladumadulu bank. A part of this current rushes through the deep channels that divide the whole of Mahlos into three banks, but some sweeps down by Mabaru, and much sweeps over the bank. Currents of 3 to 4 miles an hour were several times registered in the channels near Duravandu, but they are of less importance in the more southern passages. It is possible, however, that in the channels near Hitadu there may be powerful currents in the opposite monsoon. In correspondence with these currents the bottom of the lagoon was everywhere in the part we visited covered with hard sand, singularly barren of organic life. In the passages rock was found either flat or—especially near Duravandu—extremely rough, the dredges constantly catching up in living and dead masses of coral, etc. All this growth of living coral, however, might be, judging from our experiences in other atolls, merely in local, isolated patches, though certainly Mr Cooper's dredgings in the three passages north of Duravandu point to a general upgrowth of the whole rim reef near its seaward margin.

In regard to the land, it is evident that all or most of the reefs of the rim to the south and east had at one time a broad line of elevated rock against the sea. This extended on each more or less as a crescent, the two horns of which curved round for some distance on either side against the dividing passages. Behind this there still exists on most reefs a sandy islet. All such islands on the rim reefs, whether of sand or not, are generally washing away on their seaward faces and growing outwards on their reefs towards the inner part of the bank. On most of the reefs no definite conclusions were possible as to what causes the rock owed its origin, but in Maduwari (p. 163 and Fig. 30) and Hitadu elevation was clearly indicated. Further, no piling up of coral or of other reef material was anywhere found, so that it is reasonable to conclude that the rock everywhere was formed by elevation. The coarse and jagged appearance of the sand grains, that for some distance behind the rocky belt form the land, leads me to believe that the outer parts of the sandy areas of the islands largely owe their existence to the same change of level that formed the rock.

The seaward slopes of the reefs follow the usual form, but the presence of raised rock on the southern reefs, within 40 yards of their seaward edges, shows that their outward growth since the elevation occurred cannot but have been very small. A more marked change may be seen in points from the reefs having grown out into the passages at their seaward ends, the narrowest parts of the channels into the bank and the broadest parts of the individual reefs being generally in this neighbourhood. The bottom off these points is covered with corals, and slopes not more steeply than the reef to seaward. The lines of raised rock pass gradually round on the reefs along the sides of the passages, and do not continue out into these points. It is hence a fair deduction that these points represent a fresh growth since the elevation took place. Further there is every reason to believe that this growth is still going on, and that it will ultimately provide our bank with a complete encircling reef.

As to the lagoon reefs the account given of them in N. Mahlos (Chap. VI.) equally applies to this bank. An unusual feature of the reefs of the islands from Madu to Duravandu is

the gradual slope of their lagoon ends, the depth at about 40 yards from the reef edge in this position being only about five fathoms, whereas off the reefs in the interior of the bank and off the rim reefs in the channels, the general depth in the vicinity—20 *f.* or more—is usually reached in considerably less than the same distance. Further out off the lagoon ends of Mahrus and others of the encircling line of reefs I found no marked steep, and the bottom, so far as I could see, was covered with growing corals and other organisms. The character in these positions was that of a growing reef, and it is this outgrowth, which has built the foundations, on which the islands have become elongated transversely to the line of the edge of our bank. The singularly little growth of these rim reefs to seaward and against the passages is peculiarly interesting, and not easily explicable.

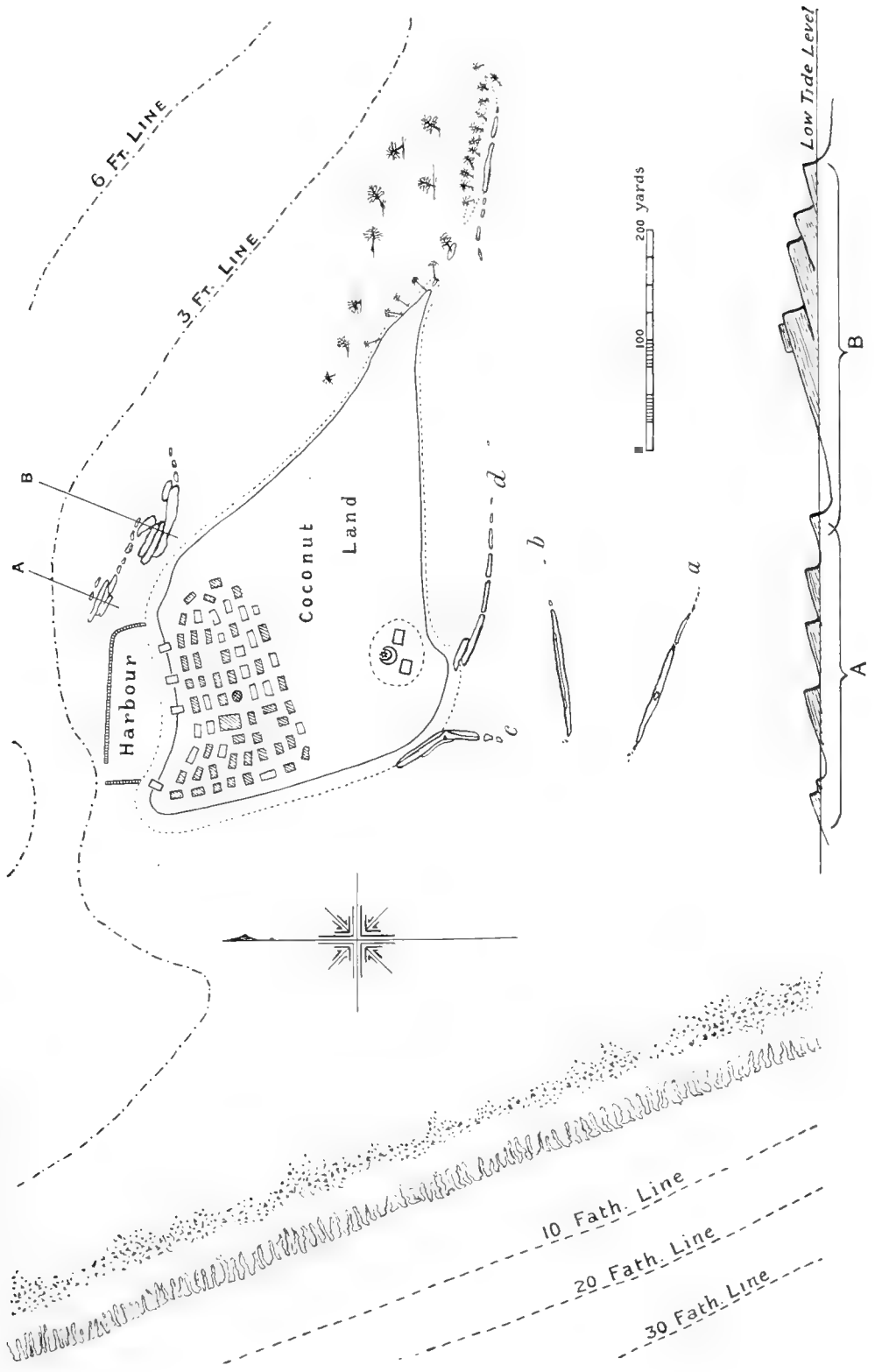
Turadu island (Pl. XIX.) is of especial interest, lying as it does on the south-west corner of the bank, where the greatest force of the S. W. monsoon would necessarily be felt. The island lies about 400 yards back from the seaward edge of its reef, and is entirely of sand formation with no trace of coral rock on any of its reefs. The seaward reef has a well-defined edge, reef flat of 40—50 yards, boulder zone of 20—30 yards, and sandy boat channel with 1—2½ feet of water, which continues round the other sides of the island in a sandy flat. The latter, however, at the extreme north point is scarcely existent, the shore sloping evenly to three fathoms in about 50 yards.

The island has in recent years been struck by two cyclones, "at the commencement of the S. W. monsoon"[1] of 1896, and in August, 1898. The former is said to have swept down along the island from the N. W., while the greatest force of the latter was experienced at high spring tide from the S. W. The combined result of the two has been to reduce the island by more than the half of its former size. Yet, it is quite evident that destructive forces were at work long antecedent to these gales, a few odd sandstone rocks on the reef to the south indicating that Turadu and Warufinur were once nearly or quite connected.

The chief characteristics of the island may best be seen in the accompanying Chart (Pl. XIX.). It now nowhere attains a greater height than 4½ feet above the high tide level, and shows loss on every side except perhaps at the N. W. point, and for about 150 yards down the W. side. The sandstone rock to the N.E. exhibits nine terraces (sections A and B), while on the beach behind a tenth is forming between the low and high tide limits. The layers have evidently been much worn down, and are hollowed out underneath; the lower ones are markedly less consolidated than the upper, and serve to fully confirm the account of the rock given in Appendix A. The different lines of this rock in the boat channel on the south side are separated by about two feet of water at low tide, and serve admirably to show the former contour of the land. The outer line *a* has traces of five terraces, but *b* of only two; the average height of each above low tide is about 15 inches, but *a* has a single undermined mass in the centre, which stands up for 3 ft. 5 in. and is about 8 sq. yds. in extent. *c* is the continuation of a firmly consolidated line of sandstone on the beach to the north of the last, which formerly extended between the low and high tide levels. The sand on the beach above it was scooped out for 8—10 yds. in one of the recent cyclones, but has filled in again. *d* is a breakwater piled up on the top of a more recent and less consolidated line of sandstone. Its position represents the direction of the beach before the cyclone of 1896 (?1898), and behind it in the small bay is an incipient formation of rock.

The S.E. half of the island runs out into a point, beyond which a sand bank shows clearly the direction of the island for a further 193 yards. It has along the middle of its south side a line of sandstone, which runs as if to join *d*; it evidently belongs to the same formation as *d*, and the complete line shows on this side of the island the destructive action of the two cyclones.

[1] The description given by the natives.



TURADU ISLAND AND REEF.

(*From the author's survey.*)

To face p. 382.

The latter is also shown by the whole sand flat behind this line being strewn with the remains of fallen coco-palms and bushes. Behind the sandstone of the S.E. bank a few bushes of *Pemphis acidula*, their roots washed with every tide, continue to exist, but the sand flat to the N. is studded with their gaunt stems, which even yet have not decayed and fallen. The same kind of bushes also grows down on the beach along the N. half of the N.E. side of the island, forming some protection to the land, but the sea has broken through the line to the south, and is now slowly but surely rounding off the point.

The whole changes at Turadu serve admirably to illustrate how great may be the action of the sea in a very short period of time. The separate lines of sandstone, however, point to the fact that such action is succeeded by prolonged periods of rest or little change, the land being almost as efficiently protected against the ordinary weather by the formation of the beach sandstone as by a line of coral rock. Nevertheless, the possible effect of a cyclone is perhaps more far-reaching as effecting the cleaning out of boat channels, sand flats, etc. The absence of sedentary life between the land and the reef at Turadu was remarkable, even the ordinary *Madrepora*, *Porites*, and *Psammocora* being absent. It was noticeable further that all coral and similar growth on the sand flat towards the lagoon—while, to judge from the dead colonies, formerly plentiful for such a position—had been killed. Even at the time of our visit there was a considerable flux along this side of the island, which would prevent the formation of fresh growth and render easy the enlargement of the lagoon.

In the whole reef on which Turadu is situated I could find no definite faro-formation. The lagoon reef of the Admiralty Chart does not exist as a definite line, in many places the slope off the sand flat of Turadu island being perfectly even to 18 fathoms, the maximum depth found towards Dunikolu. There are, however, a series of reef patches along its line, showing that it was not improbably quite correctly placed when the survey was made.

Dunikolu is a sandy island of slightly crescentic shape, lying along the E.N.E. side of a faro. The island is growing to the N., S. and E., but slightly washing away on the side of the velu. The whole encircling reef is covered with about one foot of water at low tide. To the E. it has outside the island, which is about 100—150 yards back, a distinct boulder zone, beyond which lies a flat covered with living corals and apparently growing outwards. No trace of any particular connection or of any shoal water between this reef and that of Turadu was found.

Embudu is a sandy island with a definite reef, which is on all sides at the least 100 yards broad. The beach N. and S. presents terraces of sandstone with a cliff above and in places fallen shrubs, but to the E. and W. the land seems growing. In the centre the island reaches a height of nine feet above the high tide level, the sand having been piled up by the wind.

Velengeli lies to the S. W. of a considerable shoal, opposite an extensive opening in the rim of the bank to the N. of Turadu. This channel is one of the chief passages, by which the current passes on to and escapes from S. Mahlos, and any shoal in its centre would be fully exposed to the force of the S.W. monsoon. As a result the reef presents to seaward quite the character of the regular encircling reefs, and it also has a distinct though less marked flat and boulder zone to the E. as well. The island is pear-shaped, a broad head to the west tailing off to a point to the east. It is formed entirely of small coral stones, their interstices filled in by sand, and is rather lower in the centre. It is highest at the W. end, which absolutely lies on the boulder zone of the reef, and here a series of ridges may be found due to pilings up of small stones by successive gales or cyclones. These ridges to a certain extent increase in height to the outside, and suggest a correlation with the distance of the land from the edge of the reef. Any change in the island at present is local, one mainly of gain rather than of loss, but such as there is is slow and inconsiderable.

The beach to the S. and N. of Velengeli shows a most interesting formation of rock, reaching up to the high tide level. It is a true beach formation, but consists of coral fragments, many

rounded, that have become firmly consolidated by sand and deposited carbonate of lime. In places it is being worn away and pinnacles of it left on the reef or sand flat. In their composition the rock masses simulate coral rock, but their surfaces are much more rounded and their corals are seen at the first glance not to be in the position of growth, and are mostly small broken masses.

Mutali is a sand bank, similar to Embudu, washing away slightly N. and S. but growing out in spits to the E. and W. **Mawa Faro,** which I saw only at high tide, does not differ materially from the Chart, save that its velu extends much further N. and S. and its E. reef is quite narrow. **Warufinur** lies on the Turadu reef, but further back from its seaward edge than that island. It is of sand formation, growing out N.W. and S.E. in sand spits, otherwise showing little or no change.

Hitadu is a sandy island, more or less triangular in shape, with a narrow base to the S.E. Its southern reef is about 130 yards broad, and there are on it two rocky islands to the S.E. and S.W. The appearance suggests that Hitadu is the remains of a much larger island, almost conterminous with its reef to the S. At present its shores show little signs of washing away, but on the contrary it is clear that the pointed N. end of the island has grown out considerably in recent years. **Olugeri** has a rocky beach everywhere and covers the greater part of its reef; its vegetation consists of high timber, the abode of the Lesser Frigate Bird, *Fregata ariel*. **Kanifuri** I did not visit, but its shore to the S. and S.W. could be seen in passing to be rocky, with bare tree trunks and a little fallen timber.

At **Maduwari** (see p. 164, and Fig. 30) I would draw attention to the line of coral rock, protecting the land to the S. and curving round on the reef. The prominent horns of the reef growing out into the passages on either side, together with the lie of the elevated rock, serve admirably to illustrate my contention that the reefs against the passages are growing out to meet one another, ultimately to form a single encircling reef to the bank.

Kudadu (the E. island on the Kanifuri reef) and **Mafuri** are both of sand formation. The former has an extensive formation of beach rock to the N., but the latter is only a tiny bank with two bushes of about 20 feet in height. The **faro to the north** of Mafuri had a large sandy islet, but now has no sign of the same; its velu, too, is much larger. **Mandu** is a regular, sandy islet, little or not at all changed, but the pair of reefs to the S.E. are well marked with large velu and with no 'Sandy Isles' nor 'Stony Islet.'

Fig. 95. The S.E. end of Madu, showing the lines of coral rock.

Madu, while mainly a sandy islet, has a broad rocky belt on its S.E. end (Fig. 95). The reef here is about 100 yards broad from the low tide level on the beach to its outer edge. The reef slopes comparatively gradually outside, the sea 40 yards out from its edge being only about 2 fathoms in depth. The reef flat is about 60 yards broad, and there is within it a much broken area covered with large masses of coral rock, which roughly speaking form three lines, a fourth being found in the base of the beach. Other masses also occur where the shore of the island bends round N. and S. towards the lagoon. The rocks to seaward show that the land once extended to within 30 yards of the present reef edge, so that the outward extension of the latter can have been but very small since the elevation that formed the land. As the rock passes into sand round the sides of the island a few lines of beach sandstone run out from the shore, but there is little or no erosion going on at the present time. On the other sides of the island the reef edge is at least 100 yards distant, and has within it a shallow boat channel of 1—2 feet.

Hedufuri is entirely a sandy island with broad beaches and reef edge 80—200 yards away, with a narrow sandy channel of 1—2 feet. The reef on the seaward side has a few rocky masses, so that the land would seem to have at one time extended nearly to this edge of its reef. **Kumfinadu** is a long, sandy island running out into a rocky point at its seaward end (Fig. 96). Here the island stretches out on to the boulder zone, the edge of the reef being only about 35 yards from the shore. The rock extends for about 70 yards behind the point, and on the reef continues round its seaward end in a series of pinnacles and masses on the boulder zone. Behind these the land shows rapid loss, but against the passages, although beach sandstone may occur, there is otherwise little change; towards the lagoon a sand spit is, if anything, growing out along the reef.

Fig. 96. The seaward end of Kumfinadu island, showing the rocky point and pinnacles of rock extending round the reef.

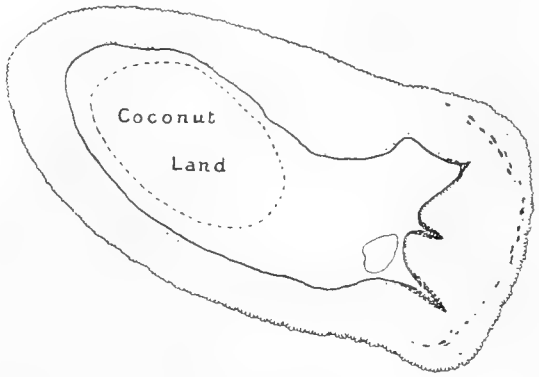


Fig. 97. Hebaridu Island and reef.

Hebaridu is on most sides at least 200 yards distant from the edge of its reef (Fig. 97). It is formed of sand, and has three spits marked by beach rock extending out to the east. Round this end, particularly in the N.E. corner, the reef has a series of large coral masses in and behind its boulder zone, that seem to have once formed part of the land. **Mahrus** is built up entirely of sand. It is larger than shown in the chart, and in shape roughly oval with a point to seaward, on which are some fallen shrubs and much sand rock. The reef to seaward is about 120 yards broad, and is characterised by its square end. From this the reef slopes inwards, so that its broadest part is that which lies directly against the sea. Round the lagoon half of the island the reef is very narrow, not attaining a greater breadth than 40—50 yards.

I have already referred to the sandstone found on the shores of **Duravandu,** another sandy island (p. 345). It occurs principally along the E. and S. sides, the island otherwise showing little change. The reef off the seaward end is about 200 yards broad, and has a well-defined boat channel. In other respects the island and reef do not differ from the last described. **Aidu** is an oval-shaped island with a crescentic belt of rock around its E. end, the rest of the island being of sand formation. As usual there is washing away on the seaward end and growth towards the lagoon. The **Mabaru** islands show that they were once connected together, lines of sandstone extending out along the reef between them. There are also the remains of an outer line of coral rock along the seaward part of their reef. Mr Forster Cooper, who alone visited this corner of the bank, was of opinion that the sandy area of the original island was formed by a series of gales or cyclones having heaped up the sand on the reef from its lagoon side. Each storm formed a ridge of sand, and the island accordingly was extended lagoonwards by a series of leaps alternating with periods of rest.

In the N.E. part of S. Mahlos there seemed to be so little change within the lagoon that references to individual reefs are unnecessary. All the islands are of sand formation, here and there losing or gaining. Usually there is a well-marked ridge of sand above the beach, blown up by the wind. A reef 40—80 yards broad commonly surrounds the land. It may have a boat channel, a few feet deep, inside, but the outer part is as a rule rather loosely built up of coral.

Kudera-helu *belongs rather to the intermediate area of Mahlos*, and is a sandy island, which has little changed in the last few years. It is surrounded by a reef 60—150 yards broad, having a distinct reef flat, boulder zone, and boat channel on each side with a few pinnacles, apparently of the elevated coral rock, still remaining. **Batala** is now a faro with a velu of about 4 fathoms to the N. The former single island to the south has become cut into two parts, a rocky island on the S.E. of the reef and a sandy one behind.

III. North Mahlosmadulu (Pl. XI.).

In every part of this bank changes of some sort or other were found, but most have been already dealt with in Chapter VI. The details about additional islands and reefs on the bank, that I could add to that account, in every way accord with the conclusions therein reached. I have, however, considered both the reefs showing the most striking changes and conditions and those which are least changed, so that with the exception of a reference to a few particular islands and reefs to illustrate special points no further account is necessary here. Among the following notes those about Rasmadu, Duwafuri, and Hudufaro I owe to my companion Mr Forster Cooper.

Rasmadu island lies E.b.N. and W.b.S. It is considerably broader at its E. or seaward end, which is protected by a line of the elevated coral rock from the encroachment of the sea, the rest of the land behind this line of rock being formed of sand. The solid rock forms a belt on the beach, and is topped by a line of boulders, piled up from the same, but somewhat admixed with sand. To the E. the edge of the reef is 50—60 yards distant from the base of the beach. The reef broadens by the sides of the island, but the widest part of the whole shoal is near its seaward end. The S. side of the island has much beach rock, but the N. shore is formed of loose sand with a single patch of sandstone near its lagoon end. The W. end of the island is growing outwards into the lagoon; it has a broad beach of sand and stones, the latter provided by the rock on the sides of the island as well as by the sweepings of the reefs. The muddiness of the water after moderately heavy N.E. winds was especially observed by Mr Forster Cooper. It seemed to be due to the washing out of the sand from a narrow boat channel of 2—3 feet which extends nearly round the island.

Fig. 98. Rasmadu Island and Reef.

Duwafuri shows considerable changes in that the large island, which is built entirely of sand, has sent out a long narrow spit towards the small island marked on the N. of the reef. The latter islet is now a mere patch of rock, over which the water sweeps in rough weather when the tide is high. The reef to the E. is nowhere less than 100 yards distant from the land, and has the regular reef flat, boulder zone—which is continuous with the N. islet—and boat channel, the latter with

a depth of 3 feet. To the N.W. of the island is a broad pool with an average depth of 1 fathom, but approaching 2 fathoms in the centre. The W. side has a broad, sandy beach, the change in which, if there be any, is one of gain rather than loss. To the S.S.E. a sand spit has been formed running out to within 20 yards of the boulder zone, which in this position is marked by the piling up of a stony patch.

The E. side of Duwafuri is remarkable even in the Maldives for its extensive loss. In the first place about 200 yards to the S. of the northern, sandy, outgrowing spit is a line of beach sandstone terraces, dipping to the N. and running right out diagonally nearly across the boat channel. This rock probably shows the former contour of the island before the sand spit grew out, the island possibly of Moresby's Chart. South of this the E. side is literally covered with fallen coconut and other trees, with here and there patches of the beach sandstone, the rock not generally in terraces and as yet in most places ill-consolidated. Many of the root masses of the dead trees still lie in the water below the low tide level—the island is not inhabited or they would have been removed by the natives for firing—one even being 80 feet out from the present shore. In one place a soft beach sandstone had absolutely formed round the trunk of a coconut tree before the latter had had time to rot, a period probably of less than 20 years.

Hudufaro (Hee-fur-ru of Chart) shows almost the same changes as the last island in a marked washing away of its E. or seaward face, little or no loss or gain to the W., and a possible growth outwards to the N. and S. The E. side has an extensive formation of sandstone, of which lines are found in a boat channel of 80—100 yards broad between the boulder zone and the beach. One line in particular was of interest near the N.E. corner of the reef, where the erosion was especially rapid; it runs out diagonally across the boat channel, ending in some masses just behind the boulder zone. No pinnacles, which could be definitely said to belong to the elevated rock, were found.

Off **Raskateen** the reef is only about 60 yards broad to the E. but it gradually increases in width around the island, to the W. being 120 yards across and having a small boat channel. To the N., E. and W. the island shows no change, but to the S. there is an outgrowth of sand. Everywhere the beach is formed of sand except to the E., where there is a mixture of sand and rock, the latter mainly the washed-out coral masses of a former line of the elevated rock. The island is peculiar in that it is surrounded by a belt of higher land, about 50 yards broad by 7 feet above the high tide level, while its central part is 3—4 feet lower.

Wadu is noticeable like most of the other islands of the rim for the extensive erosion of its E. or seaward side, the land even where the reef is narrowest lying 200 yards behind its edge. It is still more peculiar for the enormous breadth of its W. reef, 300—400 yards, a width quite unparalleled along the east side of N. Mahlos. Such growth of land as is now taking place is to the N.E. along the sandy belt between the velu and its seaward reef. The presence of a rocky island to the N. and a few rocks along the seaward side of the middle part of the reef point to the former existence of a single elongated island, before the faro formation took place.

Of the islands of the W. side I find on reference to my note-book that the statement (p. 169) that **Maregiri** is a sand island is not quite accurate. Much sand enters into the composition of the island in every part, but only the E. half is formed entirely by it. The western third has its beaches mainly formed of coral rock and loose blocks of stone, and the intervening part is intermediate. The rock, however, only forms a belt around the W. end, the middle of the island being formed entirely of sand. At the S.W. point the reef is 150 yards broad, and is studded for its inner 90 yards with pinnacles of coral rock, into the composition of which sand especially largely enters. Originally there would seem to have been a broad crescent of coral rock round the W. end of the island, but no traces of this are to be found within 40 yards of the outer edge of the existing reef, which I suppose to have grown out since the elevation for the greater part of this distance. The loss of land along the W. and S. sides is shown by the rock,

as well as by sandstone in the beach to the S. To the N. there has been much washing away in the past, but along the W. half of this shore there is now some piling up of coral masses, etc., these in one place overlying a line of beach sandstone. The E. end has no definite reef, sloping gradually to 17 fathoms, with a sandy bottom on which a few coral colonies here and there manage to live. The presence at this end of the island of an upper sand cliff of 2 feet, separated by a terrace 60 yards broad from a lower fall of 4 feet, possibly indicates a washing away. The terrace, however, does not seem to have ever been covered with vegetation, and was formed, I am inclined to consider, by a piling up of the sand in recent times.

Mudduwari has large beach sandstone masses E. and W. and a rocky island covered with trees to the S., evidently a very few years ago—the natives say 30 years—joined to the main island. Round the whole reef are a series of masses of the raised rock, showing that the original island was nearly conterminous with its reef. The large island is built up entirely of sand, but this a few feet below the surface is so coarse and sharp-angled that it would scarcely seem to have been washed up by the sea. (See also p. 165.)

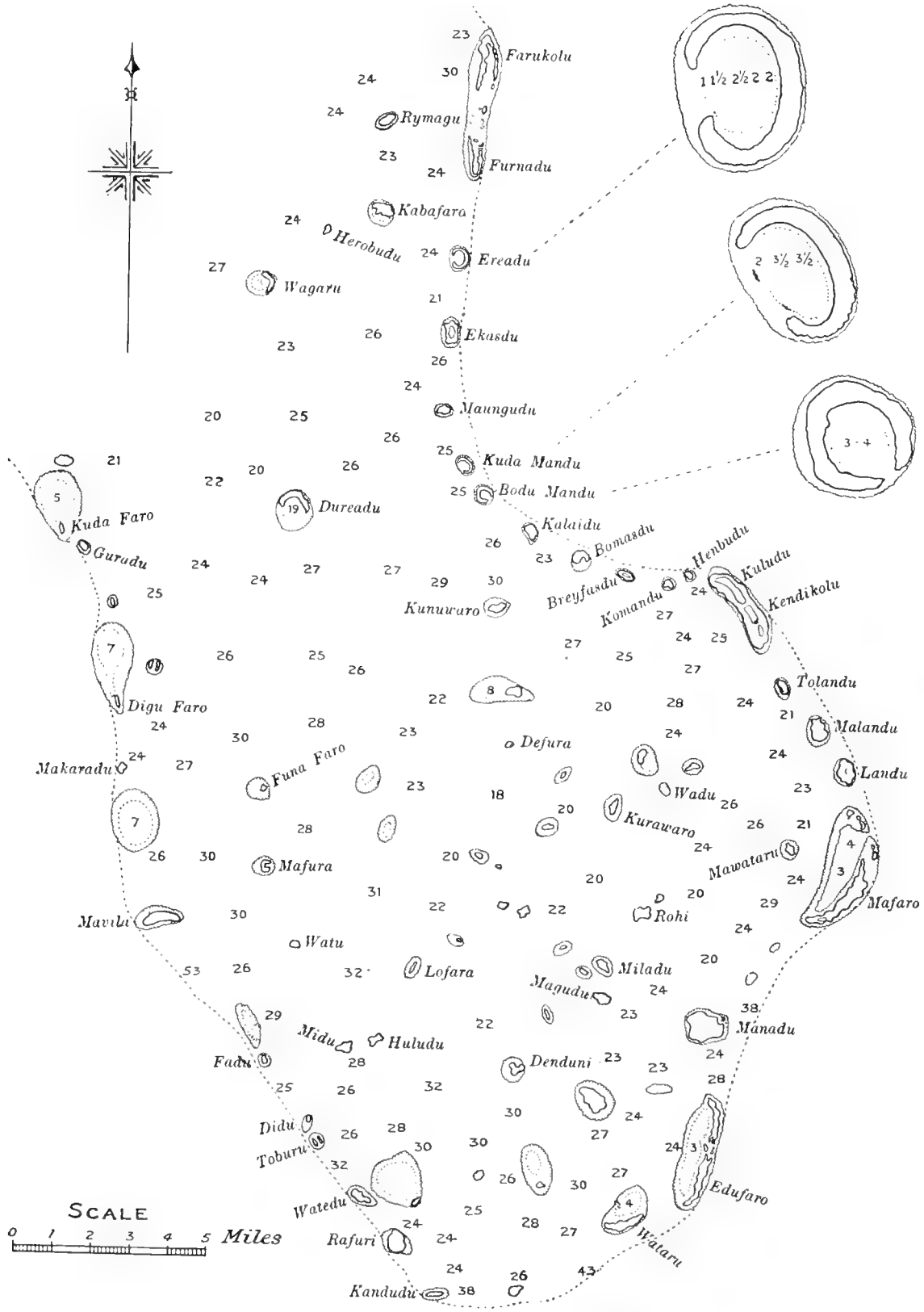
Fusmundu besides its velu is remarkable for the washing away of the shore and the formations of sandstone to the S. and S.W. The islet is composed entirely of sand, and both land and reef appear to be growing out to the east, the reef in addition having a point to the west. The reefs N.W. to **Kutai** all seem to be to some extent growing out in the direction of the current; most have some sort of a velu. On the larger are found at their seaward ends between tide marks broad boulder zones of recent formation, almost "stony patches."

IV. Miladumadulu (Pl. XX.).

This bank is arbitrarily divided for governmental purposes into two parts, to which are given different names, Tiladumati and Miladumadulu, but between which there is no geographical separation. The whole bank differs from all other Maldivan ones in its islands being so widely separated from one another that in all, or nearly all, parts almost oceanic conditions prevail. Yet, owing to the water passing for some distance over a bottom of decreased depth, there has been developed a certain amount of difference between the seaward sides of the rim reefs and those which face towards, or rise upon, the centre of the bank. Against the sea heavy breakers are found, while within even the most open part of the bank they are never of any importance. Such breakers would imply strong under-currents outwards along the slope of the reef (see p. 24), while owing to the shallow depths on the bank the currents simply diverge on either side of any reef. The plankton crossing the surface would be plentiful enough, but might not be suitably distributed by the currents over the bank. Again, the water outside would be clearer and more charged with carbonic acid gas, the main food of reef corals and nullipores, while, after crossing any part, it would be bound to have picked up some amount of dirt, and much of its carbonic acid gas would certainly have been used up and not replaced. The extremes of temperature are more widely separated upon the bank, but, the average being about the same, it is difficult to see that this circumstance could have much effect on the growth of the organisms.

Nevertheless, the openness of the rim of Miladumadulu must be of some considerable importance, since it was only[1] on this bank that we found the existence of a definite reef flat off any of the central islands, together with a well-formed fissure zone and gradual slope outside to the general level (*vide* Dureadu below). Alone in the interior of this bank also

[1] N. Mahlos is to some degree an exception (see Chapter VI.).



MILADUMADULU ATOLL WITH ENLARGEMENTS OF SOME OF THE ISLANDS.

(Somewhat altered from the Admiralty Chart.)

To face p. 389.

I have found *Lithothamnion* to be abundant on the edges and slopes of the reefs, but it does not incrust large areas, as on the true seaward slopes. Off the west of many of the east rim islands no reef flat occurs, but this is easily explicable by the consideration of the recent changes in the land, such absence of reefs being usually associated with an outgrowth of the land by the piling up of sand, or in other words with much movement of fine matter by the winds and waves.

As a whole our bank is a table-land beneath the sea with a number of gradually, or precipitously, sloping, low table-hills, all of the same height. Its interior is remarkably level, and, while there is generally a little sand covering the surface of the bottom, our sounding leads never drove into a thick deposit except close to some island. In dredging we procured a number of corals, especially near reefs, but more often the dredges came up with polished metals and quite empty. Between the islands of the east rim the bottom was rougher, and we obtained specimens of most of the sedentary animals found elsewhere in 20 fathoms. Between Mafaro and Manadu we found two coral patches of 7 and 10 fathoms, but within the bank we met with no areas which seemed to be growing up to form surface reefs.

How the islands within the bank were built up in the first place is not at all clear. In any former condition of the bank there is no reason why shoals should not have grown up on any part, provided the reef corals and other organisms once managed to obtain a firm foothold. An island like Dureadu with raised coral rock outside could only have been formed by a change of level. But the large majority of the inner islands are formed of sand, perhaps indeed all those charted as without any reefs, this absence of foundation reefs being due to the movement of the sand on their slopes preventing any growth of rock-forming organisms. Further, all these sandy islands appear to have their shores washing away, and how they have continued to exist so long it is difficult to explain. They would necessarily seem to have been created in the first place by a change of level, but the original shoals must have been built up of rock rather than sand. Not only are these islands themselves washing away, but, since they have no enclosing reefs or protecting growth of organisms on their slopes, their foundations are being removed down to the level of the floor of the bank. It accordingly appears probable that the sandy islands were formerly protected by belts of elevated rock against the sea, which have now been completely removed, but the evidence, from which their former condition might be deduced, is very meagre.

It is most extraordinary that all the banks of the east rim should have land. Round their seaward sides the reef flats are in all cases very narrow, and the islands would appear to have been at one time almost conterminous with their reefs. The seaward beach is in every case of rock, and the reef flat off the same is studded with pinnacles and masses of rock; its surface and edge are bare and it shows no definite outgrowth in any place. Where there is no land, as in the middle of the reef of Furnadu and to the north-east of Mafaro the reef flat is broader, and the reef has the regular fissured edge characteristic of an outgrowing one. Accordingly, the absence of outgrowth off the land must be ascribed to the mud and dirt which is being continually swept out from it, preventing the growth of the building organisms. To the west of the same rim reefs, wherever a definite flat exists, its edge has the usual outgrowing appearance, but owing probably to the shallower water this is often more marked than to seaward. As already mentioned, a true reef is, however, seldom found off the inner ends of the islands of the east rim, owing to the currents forming eddies behind their reefs and constantly shifting the sand.

The presence of pools of more or less fresh water in many of the east rim islands is remarkable. All such must have been at one time connected with the sea, as they all have fish and prawns identical with, or closely allied to marine species. In addition their shores are fringed with mangroves, which could only have been introduced when their waters were in open communication with the sea. Some of these pools were perhaps cut off by sand being piled up on their lagoon sides, in particular those with shallow water in Ekasdu, Kendikolu, and Landu seeming to have been formed in this way. The size of the islands and the fact that the sand, instead of being piled up directly against the rock, was deposited at some considerable distance out on the reefs, thus cutting off pools of water, allow us to infer that the original reefs before elevation were flats of considerable breadth. Further, the deeper pools of Ereadu and the two Mandu, so greatly enclosed by land as they are, are not likely to be of recent formation, so that some of the reefs before elevation were probably themselves definite faro. A still more remarkable reef is that of Dureadu with its velu of 18 fathoms, but the weather—and want of drinking water—prevented a thorough investigation of this faro.

The condition of the Miladumadulu-Tiladumati bank is quite unparalleled elsewhere in coral reef regions, and its topography would be almost inexplicable if it had been examined alone. The bank compared with North Mahlos and others shows that it is only an early stage of atoll formation. Nevertheless, many points in Miladumadulu are not clear, but it is probable that Prof. Agassiz with a more complete examination extending into Tiladumati and to deeper depths outside the bank will be able satisfactorily to elucidate these.

Guradu has on all sides stony beaches with coral rock. To the N.E. there is practically no reef, the same condition being found as to the N.E. of Minikoi, where the waves break about 20 yards from the shore. This condition merges on either side of the island into a definite fringing flat, to the S.W. 50 yards across. The shore, S. and E., has many large dead tree trunks, and on all sides masses or pinnacles of the coral rock were seen. The island on **Kuda-Faro** is all sand, and situated well behind its reef, which is a faro with well-marked velu.

Dureadu is a crescentic-shaped island, covering almost half the circumference of a round faro, $1\frac{1}{4}$ miles in diameter. The beach against the velu is all sand, the top about 2 feet above the high tide level. It shows much movement, its sand apparently shifting to the W. in the S.W. monsoon and to the N.—and probably N.E.—in the N.E. monsoon. On the whole there would appear to be a little loss as there are a few fallen trees, etc. A sand flat, narrower to the N., fringes the shore against the velu, but the term sand flat is here a misnomer, the shelf having a mere covering of sand on a solid rock, which round the ends of the island—to the S.W. being 60 yards broad—forms a continuation of the reef flat. Within the crescent on the flat there are no corals, but a few shoals built up of their colonies are found in the velu. Twelve soundings on the submerged reef to the S. gave depths varying from 3 to $5\frac{1}{2}$ fathoms, so that probably there has been little or no change. I could not see the character of the bottom on account of the heavy weather having made the water quite milky.

To the N.W. of Dureadu I. on the outside is a shallow, incipient bay with sand shores and a reef 120 yards broad, consisting of a flat, boulder zone and boat channel—that is, of the same parts as on any rim reef freely exposed to the full force of the ocean. In the boat channel and on the boulder zone are a few masses apparently of upheaved rock. These are rather more numerous to the S.W. and to the N., where the island runs right to the boulder zone of the reef, and has a rocky belt along its shore. To the N.N.E. there is simply a reef flat of 25—30 yards in breadth, quite similar to any seaward one, save that it is without the regular fissured and buttressed edge, but

these parts are also absent off many of the E. rim islands of the same bank. On its inner part lie many flattened dead slabs, the bases of large colonies of *Madrepora*, merging above into the beach, which is partially composed of them and partially of the raised rock. No part of the latter attains a greater height than that of the high tide level, but the loose masses on the top of the beach form a narrow ridge about 10 yards broad and 2 feet higher. Behind this again the surface of the land is a little below the high tide level, and hence, being moistened with every tide, supports a mangrove swamp. The breadth of the island in the middle of the N. side is 230 yards, of which the belt of rock occupies the outer 60—70 yards.

Rymagu is surrounded by a definite reef flat, 20—40 yards broad and formed of rough coral rock, completely exposed for about 1 foot at low tide. This possibly extends under the whole island, for I was informed that the wells all pierce the rock, this perhaps accounting for their relatively excellent water. The island is mainly formed of sand, but its shores have a certain amount of boulder material from off the flat.

The **Furnadu** reef has two U-shaped islands with their open ends facing one another. The conditions are most readily seen by the examination of the accompanying map (Fig. 99), a comparison of which with Moresby's chart is interesting. In the first place it may be noticed that the seaward limbs and those parts of the islands, which lie to the N. and S. of the reef, are of rock, while the areas against the interior of the bank are built of sand. On the outer shores of the islands off the rocky parts the reef is narrow,—nowhere more than 50 yards across—and there is a little washing away, whereas against the sandy parts there is a broad reef with no sign of loss in the land, but, if anything, a gain especially of the projecting points. On the inner shores of the islands on the contrary we found everywhere a considerable loss, most obvious in those parts to which the sea can readily find access, the innermost shores being in addition protected by mangrove swamps fringing the land.

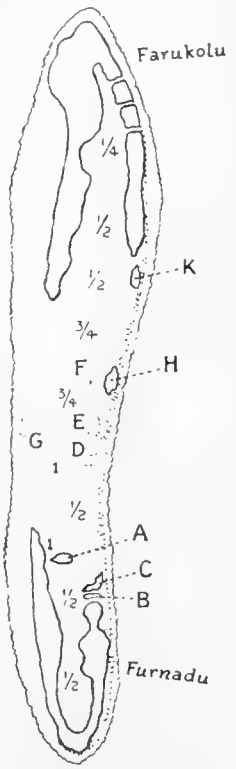


Fig. 99. Furnadu Islands and Reef.

Of the new islands that marked *A* has been formed by the washing away of the W. horn of Furnadu, from which it is now separated by a channel 6 feet deep. The sea sometimes sweeps across near the end of the E. horn of the same island, and will sooner or later cut off its head to form a fresh island. *B* and *C* are stony patches rising 2 or 3 feet above the high tide level with spits growing out to the W.; they lie just within the boulder zone of the reef, and are covered with loose, coral fragments. *C* has a single coconut tree about 7 years old, while *B* is quite bare; neither have signs of any former timbering, and this fact, together with their positions, leads me to consider that both probably are of recent formation. *D*—*G* are sandbanks awash, but *H* is a stony tree-covered islet that has formed in the same manner as *B*; it almost completely covers the boulder zone outside itself. Finally, *K* has been separated from the seaward horn of Farukolu, but this whole limb has now been cut, in addition, into three islets by three narrow canals which have formed across it from the outer reef. These are peculiar, in that in the largest the minimum breadth is not more than 20 yards; they average 3—4 feet deep, and have almost straight-cut sides as if chiselled out by man. Their bottoms are formed of bare rock, and have a slight growth of coral, but the reef flat outside them rises to the usual level on seaward reefs, i.e. that of low tide. Lastly, the island between the two limbs of Farukolu no longer exists, nor was I able to trace definitely any junction of the same with Farukolu, though to judge from the general changes found elsewhere on this reef it seems almost certain that it has become joined to its W. horn; much of its inner or east side must have been washed away in any case.

The seaward reef to the S.E. of Furnadu, beyond the boulder-covered beach, is only about 30 yards broad, but towards the middle of the island reaches about twice this breadth. In its inner part it is very rough, but with few loose masses of rock, giving place outside to an absolutely bare reef flat with a well-marked edge which continues evenly against the sea with practically no fissure formation. The whole right up to the edge is scattered with pinnacles, masses of the elevated rock. Many of these are of extraordinary size, and a considerable proportion attain a height of 7—10 feet above the reef flat, about 2—5 feet above the high tide level. Most are undermined somewhat, and the surfaces of all are much worn. They show their composition fairly well, but the force of the sea is too great to allow many upstanding coral colonies to be worn out of the rock. At the south end, on the inner side of Furnadu, at the base of the U a number of similar masses were found, which in their corals clearly showed their origin to be due to a small elevation.

While to the S. of Furnadu almost the whole seaward reef is covered with rock masses, to the N. they become continuously fewer and more scattered. Beyond the island a few are found on the boulder zone and inner part of the reef flat the whole way along to Farukolu, but they gradually decrease in size further N. Opposite the centre of the shoal the E. reef is much broader, and has the regular reef flat characteristic of seaward reefs, the edge however being more regular than is usual. Lastly, off Farukolu the reef is about 60 yards broad, the outer 40 yards of which form an almost bare and typical reef flat, while the inner 20 are covered with rock masses.

The W. reef has outside an only moderately steep slope with a broad area of growing corals, of which 20—30 yards of its inner edge reach the low tide level. Inside this lies the sand flat, which against the land forms the boat channel, but between Farukolu and Furnadu, where the whole reef narrows somewhat, continues as a great sand flat with nowhere more than 3—4 feet of water at low tide. On it sedentary life of all sorts is singularly scanty, the whole being covered with loose sand, which is washed up by the wind into temporary banks. The ordinary sand-living organisms also, such as *Sipunculus*, *Ptychodera*, and *Holothuria maculata*, are curiously rare except within the horns of the main islands.

Ereadu (Pl. XX.) is a crescent-shaped island enclosing a velu or basin with $2\frac{1}{2}$ fathoms of water. Round its outer shore lies a belt of stony land, varying in breadth from 45 yards in the middle of the E. side to 80—90 yards near the points. Outside this to the E. there is no reef flat, the slope commencing from the base of the beach, which is 10 feet high. It is very gradual for about 40 yards out, where the depth is only a fathom or so. N. and S. a flat of about the same breadth at the low tide level is found. A singular point is the complete absence of pinnacles and of any definite masses of coral rock. The whole stony belt is covered with loose corals, but the latter are not rounded off in any way, as if thrown up by the sea. This fact, together with the presence of a definite, high ridge behind the beach, makes it difficult to suppose that the corals can have reached their present position save by elevation. Yet the coral blocks looked singularly fresh, although the inner 20 yards of the stony area were formed mainly of *Porites arenosa* colonies, many 7—8 feet across, a coral which does not grow to any size on the seaward sides of reefs. Near the points the rocky belt stretches across the whole island, and is formed of small fragments, etc., obviously piled up by the waves. The points themselves show distinct outgrowths towards one another, which in time might close in the central basin of the whole reef, turning it into a lake or *kuli*.

The sandy area fringes the velu to the N., S., and E., and its shores are everywhere to some extent washing away. Broad sand flats fringe the beach to the N. and S., but in the centre of the E. side the shore slopes directly into the lagoon, a depth of 2 fathoms being reached within about 20 yards. A reef joins the points of the island, rising generally to the low tide level, but with two channels serving for small boats. It is mainly covered and apparently formed in its upper few fathoms by massive colonies of *Porites* (including *P. arenosa*)

and *Goniastraea*, and towards the inner part of Miladumadulu bank falls off to 20 fathoms in about as many yards.

Ekasdu is fairly accurately represented on the chart and, if it be bisected in a N.N.W. and S.S.E. direction, the seaward half would be found to be formed of coral rock and the lagoon half of sand. The reef N., S. and E. is about 40 yards across, and consists of a bare flat with near its beach an occasional pinnacle of coral rock. To the W. the reef is much broader, varying up to 120 yards, and has all the characters of the W. reef off Furnadu. The land shows little loss or gain, but there are several lines of sandstone on its W. beach; to the S.W. a point is growing out by the piling up of sand. The central pool or *kuli* is as charted, and according to the natives has 9—12 feet of water in its centre; its water is now quite fresh enough to be pleasant to drink. The presence of mangroves against the pool, and of an enormous number of a peculiar species of prawn, *Leander gardineri*[1], in its waters shows that it must have been at one time connected with the sea.

Maungudu resembles Rymagu in having all round the land a reef flat, 20—50 yards broad, and almost completely exposed at low tide. The outer half of this is in most places bare, but the inner is much strewn with large rocks or else consists of a rough coral rock, the whole averaging perhaps 18 inches above the low tide level. Inside this the beach is mainly formed of coral masses, but sand—of which the central, lower part of the island is entirely composed—enters largely into their composition.

Kuda Mandu (Pl. XX.) needs no special description on account of its resemblance to Ereadu. Indeed, the charts are almost interchangeable, the only differences being in this island having its opening to the S.W. and its basin $3\frac{1}{2}$ fathoms deep. The whole shore of its velu except to the S.E. is being washed away. The reef joining the ends of the island is well-formed, and reaches the low tide level. The outer part is very rich in corals, and slopes to only 2 fathoms in about 100 yards. Noticeable on its inner part is a line of elevated rock, 36 yards long and exposed for 4 feet at low water.

Bodu Mandu (Pl. XX.) resembles the last, but its opening lies to the S.E. The island is a thin rocky belt to the N. and E. with a reef about 30 yards across. To the W. it is much broader and all formed of sand; the reef is about 150 yards across in the centre, and has a number of masses of rock, showing that the land once extended right out to its edge. The land to the S. is built up of stones and sand, and is very narrow. The opening is joined by a reef similar to that off the last island, but narrower. Behind it the lagoon shore is protected by mangroves, but near the opening there is some washing away. My visit occurring at low tide, I could not enter the velu, but the natives state that it has a maximum depth of 4 fathoms.

Kalaidu has a stony belt, 30—40 yards across, round its N. and E. sides with a reef flat 40 yards broad, running out into a long point of shallow water to the N.E. The rest of the island is of sand, but there is no reef, the shore sloping gradually to 3 fathoms in 60 yards, after which comes the usual steep. There is little change save in the S.W. point, which is perhaps growing out. Behind the belt of rock is a low, swampy area, about $1\frac{1}{2}$ feet below the high tide level, now covered with coconut trees. The latter, however, are growing in a mud, such as—of all the vegetation of the Maldives—only a mangrove swamp forms, so that probably this part was at one time open to the sea. The former shape of the land could not be traced, largely owing to the sand area having been raised 2 or 3 feet by the agency of the wind.

Bomasdu resembles Kuda Mandu in its shape, outer beach, lines of stone and sand, and washing away on the side of its basin, but the island is not growing at its points and covers

[1] *Vide* "Land Crustaceans," by L. A. Borradaile, vol. I. pt. 1, p. 98 of this same Publication.

only the half of its reef. The reef edge to the S. is 750 yards distant, and has inside a bare sand flat with maximum depth of $1\frac{1}{2}$ fathoms.

Breyfasdu has the usual stony belt and reef round its N., and to some extent round its E. and W. sides. Behind there is a mangrove swamp, and the rest of the island is of sand, showing washing away on almost every side. The reef to the S. is 100 yards broad, and has a buttressed edge covered with nullipores—precisely the same as a purely seaward reef—with a boulder zone, behind which a few pinnacles of the elevated rock occur on the flat.

Henbudu is mainly formed of sand, but its beaches are much strewn with boulders. There is a definite reef flat on all sides except the W., generally at least 40 yards broad, the inner half scattered with loose boulders and with a few pinnacles of rock. Near the N.N.W. point is a small pool of water in the flat, about $1\frac{1}{2}$ fathoms deep, but elsewhere the reef is not to any extent hollowed out. Along the W. side the structure is, so far as I have seen, unique in the Maldives and elsewhere. The beach is formed mainly of boulders, and falls 7 feet in 14 yards to a smooth or boulder-strewn flat of about 8 yards in breadth, and averaging nearly 1 foot above the low tide level. This slopes in about 25 yards to 1 fathom or so, but then a number of dead rock masses arise in a line parallel to the beach up to or a little above the low tide limit. Beyond this the slope, which is bare of all organic growth, continues, tailing off finally in a steep about 18 yards further out. The outer line of rocks continues at either end into the outer edge of the reef flat, where the latter exists, suggesting that it shows the former extension of the reef round the whole island. This is of course quite possible, but, if so, it is the only definite case of solution that I have seen within the Miladumadulu bank.

Kendikolu is one of the largest islands of the Maldives, but only a small part of it is capable of cultivation. It has a rocky belt against the sea with a similar reef to that off Ereadu, both together averaging about 150 yards in breadth. This passes somewhat abruptly to the N. and S. into the sandy part of the W. side, which has no reef but a sandy growing beach with isolated coral patches off the same, sloping gradually to 18 or 20 fathoms in about 200 yards. Down the centre of the island separating the two areas is a series of three lakes, surrounded with mangroves, and separated from one another only by banks covered with the same trees, not improbably in the first place artificially erected by the natives of the island. These lakes are filled with fresh water, but do not attain a greater depth than 5 feet; they average in breadth together with their mangroves about 500 yards. Two saltwater fish, that commonly live in backwaters and ascend rivers, *Chanos salmoneus* and *Gobius criniger*[1], were found in them.

Tolandu, **Malandu** and **Landu** all have stony belts, slightly washing away, with the usual narrow reefs to the N. and E. and sandy shores to the S. and W. The first two islands have broader reefs to the W. with pinnacles of rock, but that off this end of Landu is no broader than that off its N. or E. shore. A mangrove swamp is said to occur within each of these islands, but I myself only saw the one in Landu. In this island there is a narrow freshwater lake to the N.E., surrounded by mangroves and separated by a rocky belt of 60 yards in breadth from the sea. The area of the swamp is now much restricted, but numerous mangrove swamp plants occur throughout the centre of the island, and the surface of the ground is riddled with the large holes of *Cardiosoma carnifex*, an essentially mangrove swamp crab. The animals of the kuli include three fish, *Gerres maldivensis*, *Mugil coeruleomaculatus*, and *Barbus vittatus*[1], and a prawn, *Leander debilis*.

Mafaro west reef (Fig. 100) is nowhere exposed at low tide, and has a very bare appearance, being largely sand-covered, with here and there a patch of low corals. Inside this is a mud flat

[1] *Vide* "On the Fishes from the Maldive Islands," by C. Tate Regan, vol. i. pt. 3, p. 279 of this Publication.

which surrounds the whole velu, being only broken opposite the N.E. passage. The maximum depth found in the velu was 4 fathoms, the central part of the basin being a uniform flat at about $3\frac{1}{2}$ fathoms. The N.E. passage towards its lagoon end has a maximum depth of $2\frac{1}{2}$ fathoms, but to seaward it shallows still further, and between the outer points of the reef—which are 130 yards distant—only reaches a depth of $1\frac{1}{2}$—2 fathoms. Throughout its whole length the channel is studded with growing coral shoals, almost reaching the surface, with towards its lagoon end sandy areas between, but towards the open sea with almost its whole bottom covered with sedentary organic life.

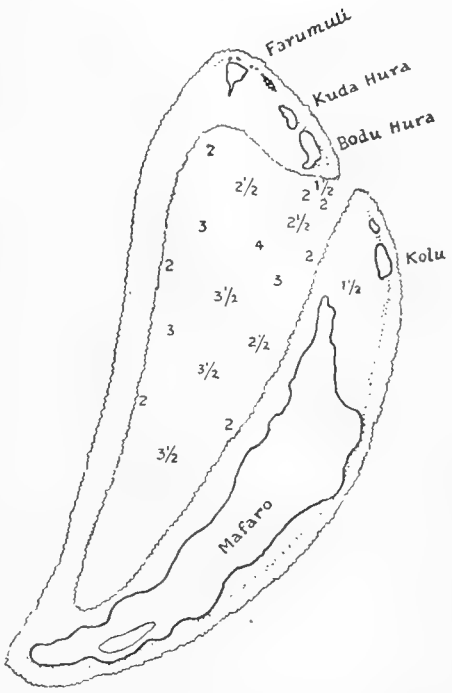


Fig. 100. Mafaro Island and Reef.

Round the E. side of **Mafaro** the reef, where no land exists, consists of the usual reef flat, boulder zone—either of the two with pinnacles of the elevated rock—and sand flat. Wherever rocky land is found there is a reef, quite similar to that off Ereadu. The northern three islands are all of rock and appear at one time to have been connected, being joined along the reef by a succession of pinnacles of the raised rock; Farumuli too has traces of a mangrove swamp in its centre. All the islets at the present time are slightly washing away to seaward, but sending out points of loose stony materials towards the lagoon, against which Bodu Hura has a small accumulation of sand. Kolu is separated from the main island by 6—9 feet of water, and consists of rock to the E. and sand, very rapidly washing away, to the W. The main island has behind the last a sandy spit strewn with fallen bushes to the E., but possibly slightly growing out to the N.W. S. of this the island has on the N. and S. thirds of its E. side a narrow rocky belt, between which the sea has cut into the land, and is forming a bay. At the S. end is a mangrove swamp. The lagoon side of the island shows no definite change but, if anything, is extending outwards by the piling up of sand.

Manadu has a narrow stony belt to the E. with a smoother and more marked reef flat than the northern islands of the bank. To the N.E. it has three rocky islets (Fig. 101) that have been cut off by the sea from the main island. With the exception of a rocky seaward belt the latter is formed of sand, which is growing out especially to the N.N.W. and S.S.W. To the N. and S. the reef is 100 yards distant, but to the W. there is no reef, only a series of coral patches to 2 or 3 fathoms, 40 yards from the beach, and then a gradual slope to 18 fathoms in an additional 70 yards. An interesting point in traversing the island from W. to E. is a series of sand dunes, almost ridges running N. and S., and varying up to 21 feet in height. These possibly show waves or periods in the growth of the island by the accumulation of sand to the W. They could not on account of the vegetation have been heaped up save in the immediate proximity of the sea.

Fig. 101. Manadu, N.E. of the Island showing erosion.

Edufaro (Fig. 102) has on the W. side a very distinct surface reef with a single boat channel to the N., enclosing a lagoon of 2—3 fathoms. It has two main islands, which have the usual rocky belt and narrow reef to seaward. The sand has for the most part been

removed from the lagoon side of the land towards the N. of the bank, while it has somewhat accumulated to the S. In the centre, where the islands approach one another, there is marked washing away of the land and much fallen timber. The N. end of the S. island has been cut off and broken into four separate islands, three on the reef flat mainly formed of rock, and one against the lagoon of sand.

Miladu is a sandy islet with a stony beach of broken corals and of sandstone to the N., S. and E., where there has been considerable loss. There is no definite reef round the land, but a belt of shallow water is found with patches of corals and other organisms arising on a sandy bed. **Magudu** and **Rohi** were not visited but, viewed in passing, appeared to be precisely similar in structure to the last island.

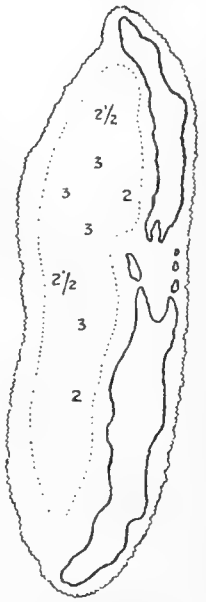


Fig. 102. Edufaro Islands and Reef.

V. Fadifolu (Fig. 103).

Fadifolu ranks in the Maldives as one of the more circumscribed and definite atolls of the group on account of its single line of reef, almost completely encircling save to the S.W., and the open nature of its lagoon, which is free from any large shoals and islands. In respect to the latter the last two islands left, the Innagiri—shown in the chart of 1836—have been completely washed away. Records, however, are still preserved of four other islets on shoals in the centre of the atoll-lagoon, that had gone even before Moresby's chart was made. One of these of peculiar sanctity was stated to have existed on a reef marked on Moresby's chart with soundings of from 10 to 15 fathoms. For an island to have been situated anywhere in this area its condition must have been very different formerly to that of the present day, consisting as it does of a number of very small reef patches, occupying a considerable area, none large enough to support land. In respect to the present actions on all these shoals within the lagoon our observations were not sufficiently numerous to deduce any changes, but by analogy with the more enclosed parts of Mahlos it is clear that they are breaking up into smaller reefs and being removed.

The relatively dead nature of the inner parts of the encircling reefs everywhere against the more enclosed areas of the lagoon of Fadifolu and the changes, more particularly noticed at Inawari, Naifaro and Difuri, leave no doubt but that the lagoon is increasing on all sides at the expense of these reefs. In this connection it is interesting to observe that our dredgings showed the bottom of the lagoon to be quite smooth, with no signs of growing organisms, that might in time form definite shoals, and covered with a thin coating of sand, in most places on a hard (? rock) bottom.

A close comparison of the present day conditions of the passages into the atoll with those of the chart was impossible though eminently desirable. On each side of many of these channels towards their seaward ends distinct points were found, extending out from their bounding reefs, which might by growing together ultimately obliterate at least many of them. Instances were found, too, of separate reefs of the rim that have become fused. Our impression certainly was that everywhere the rim reefs were growing together to form a single enclosing band, though of course there are physical reasons against its being likely that this consummation can ever be completely effected.

In connection with the last question I more particularly investigated the passage next north of Naifaro, which owing to points having grown out from the reefs on either side is narrowest at its extreme seaward end. The passage has, it should be observed, a bend in the centre off the south end of Madewaru island, the foundation reef of which extends relatively further south than marked on the lagoon side. Within a few yards of the reefs on either side of this passage I got depths of 13, 14 and 15 fathoms with a depth in the absolute centre (both in its length and breadth) of the channel of 19 fathoms, which apparently continued without decrease to the floor of the atoll-lagoon. Going outwards, however, the bottom rises to a line with 12—13 fathoms along the seaward edge of the

Fig. 103. Fadifolu Atoll, considerably altered from the Admiralty Chart, with which it should be compared.

passage between the points of the reef. In the middle and inner part of the channel, especially near the reefs, a fauna consisting of *Dendrophyllia*, Gorgonians, Alcyonaceans, sponges, etc. was obtained without difficulty, the bottom being relatively smooth. Along the outer ridge on the other hand dredging was difficult on account of the large, heavy coral masses, but a quantity of the material covering the bottom was secured. Among it some of the ordinary reef corals were found growing, but the greater part consisted of dead coral, held together by sponges, Tunicates, Polyzoa and more particularly *Lithothamnion*. Much of

the dead coral from this position was in small masses, as if due to a piling up by the currents, but this appearance, as that of the relative absence of living corals, may have been due to the powerlessness of our dredges to give us a real idea of the nature of such a bottom. On each side of this ridge the reef was in its slope (11 fathoms in 16 yards) less steep and dead than further within the channel, being covered with much *Madrepora* and nullipore growth. There seemed then to be a definite upgrowth along a line across the passage almost against the outer slope of the atoll, a character which I was also able to detect in the next two channels to the south, but which I was almost unable to trace so clearly elsewhere in the whole Maldive Archipelago. It is interesting to observe that in the passage north of Naifaro on Dec. 26th, 1899, no current was found on the surface with a rising tide and wind of force 6 from the north-east, while in six different positions, 8—16 fathoms deep, currents setting seawards were found, varying in force from $1\frac{1}{2}$—$3\frac{1}{2}$ miles per hour.

The various changes of land and sea are dealt with below for the islands severally, but it is remarkable that on none of the reefs we visited to the west did we find any rocky land, any trace indeed of elevated rock. To the east on the contrary there still exist at least the remains of an almost continuous line from nearly the north to the south point of the atoll. The sandy land of the lagoon side was probably piled up from the lagoon behind this line of rock, and there are now places, where the same process continues. If any rock ever existed on the west rim, it is impossible to believe that no trace of it would have been left. At the same time sand areas without rock could not have been formed under the sea except at some considerable depth. It hence follows that the sandy islets of the west side must have been formed by sand washed up from the lagoon, and it is necessary to suppose that the reefs of the west rim were less perfect before elevation than those of the east rim, and still some distance below the surface of the water.

Kani Hura, Fehingili, and their reef to the N.E. of the atoll (Fig. 104) are quite irreconcileable at the present day with the old chart, so much so indeed that it is extremely difficult to see what changes have really taken place. The N. end of Fehingili is of stone, and appears to be growing out, while the S. side is washing away, the island marked *x* having been cut off from the same. South of Fehingili along its reef is a series of no less than seven new islets, which are apparently of stone outside and of sand within, their outer edges resting on the boulder zone, beyond which is a well-defined reef flat. Kani Hura has a fringe of rock to the N.E., which side shows generally a loss. The rest of the beach is of sand growing out, slightly to the W., but more extensively in a spit to the S.W. The seaward side of the S. end of the island shows a line of beach sandstone along the reef. Beyond this there is a flat, a kind of boat channel, but not hollowed out, and with some patches of loose stones. Further out again is a line of the elevated coral rock, extending along the reef for some distance to the S., but not elsewhere found on its surface. These masses of rock in this position lie on the inner part of the reef flat, but in other positions there is a well-defined boulder zone, the rocks of which are represented in this situation by the loose stones between the reef flat and the beach of the island. The reef, examined as a whole, shows from this line of elevated rock that a great island must have at one time extended to the S., while probably all the land to the N. is of quite recent formation with the possible exception of a patch near the northern passage.

The reef to seaward of Kani Hura, and indeed everywhere that I saw to the E. of Fadifolu, has the typical outer slope, reef flat and, where no land is present, boulder zone. To the W. of Kani Hura there is a sand flat sloping to a velu, which extends nearly along the whole length of

the reef with a depth of two or three fathoms, smooth sandy bottom with little or no sedentary life. An irregular line of reef with a series of surface patches, through which a passage may anywhere be found, forms a barrier for this pool against the atoll-lagoon. Along its whole length the character of this reef varies considerably, its surface being in some places covered with knolls of coral, and in others almost bare; everywhere a characteristic, almost perpendicular, fall to the lagoon was found. Of the two shoals represented to the W. of Kani Hura I could see no signs, though all those marked in the chart near the N. passage were quite distinct.

Furifaro is the southernmost of two reefs—the two reefs to the N. shown in the chart have become completely fused—separated from one another by a quite narrow channel, almost a canal. The island itself is washing away to the W., but growing out to the N. and E. It presents a peculiar appearance, being covered with low shrubs to the E. rising to immense *losa* trees (*Morinda citraefolia*) to the W., where the shore ends in a small cliff. To the N. there is a steep, sandy shore, which falls practically to the bottom of the N. channel. E. the reef is the same as off Kani Hura, but W. it differs in being covered with living coral colonies, presenting here quite the appearance of a growing reef. The reefs in the channel to the S. of Furifaro are flat-topped and reach the low tide level.

On the western side of the atoll **Kuredu** is washing away to the S., but, if anything, being extended by the piling up of stone to the N. and along by the side of the passage, where its enclosing reef is very narrow. The S. island on this same reef, which the people remember to have been covered with coco-palms, is now a mere sand bank with three small trees.

Komandu is of sand with a large reef, to which are now united the reef to the N. and the small patch to the S.E., but about half of the latter does not now exist, so that the passage is fairly clear. The island is washing away N.E. and S.W., but growing S.E.; to the S.W. there are three lines of beach rock running out upon the reef, which at its edge consists of a series of separately rising coral patches.

Inawari is a sandy island increasing both N. and S., but very decidedly washing away to the E., where I found that a former graveyard, at least thirty yards across, had been very largely removed, the whole shore being strewn with human skulls and various other bones. Off this part the natives of the island have erected breakwaters, which three times in the last forty years have had to be renewed. Outside at the low tide level there is a dead flat of coral rock—a reef flat—which ends precipitously against the lagoon. The natives state that the reef is narrower on this side than when they were young, and that both it and the land are being washed away at the same rate. The reef to the N. appears to be growing out so as to close in the passages on either side of our shoal, and there does not seem to be any separate reef as that marked off the S. end. A comparison in this neighbourhood with the chart is impossible, but it is clear that the island was originally placed too far to the W. on its reef. The presence of a clear, broad passage—we anchored in it after twice tacking—on the E. side is not to be reconciled with the chart, unless one supposes that the W. reef has really been washed back, a supposition which its dead condition shows clearly to have been quite possible.

Madewaru is all of sand, washing away rapidly to the E. and less quickly to the W., while apparently growing out at its N. and S. points. It is, however, always very difficult to decide about the changes of sea-swept points, where as in this case practically the whole island is covered with such bushes as *Scaevola koenigii*, *Tournefortia argentea* and *Pemphis acidula* without any high trees.

Naifaro is, like the last island, of sand, and shows the same changes. Its reef on the E. side is all dead, and nowhere more than 120 yards broad. At its edge is a breakwater erected by its people, outside which a depth of 12—15 fathoms was found in 3—4 yards, the slope being almost perpendicular and with no animal life. All the islands to the S. of Naifaro as far as those on the Kanifuri

reef differ in no respects from the northern ones, being formed of sand and washing away towards the lagoon, and perhaps against the sea, while more or less growing out at their ends. Their reefs to seaward differ though from those of the E. side of the atoll in having no definite boulder zones, only two zones being found, the sand flat (or boat channel) and the reef flat. The former differs in no respect from that occurring elsewhere, save that coral life is especially abundant upon its surface, but the latter is rougher, though less fissured at its edge, with more growing coral colonies and other sedentary organisms than is usually found on the seaward reefs of the Maldives. The E. sides of all are singularly barren, with a peculiar dead appearance and much algal growth.

The condition of **the great S.E. reef** of the atoll is best shown by the chart (Fig. 104). The reef is continuous from Faidu to Aligau, and, indeed, there are no considerable breaks on the E. side except those on either side of Furifaro. N. of Faidu is a small stone heap on the point of the reef against a very narrow passage. This is joined to **Faidu** itself by a line of rock, outside which the sea breaks at only a distance of about 60 yards. Round Faidu island the rock forms a belt against the sea, 7 feet above the high tide level, passing outside into a reef flat, studded on its inner half with pinnacles of the raised rock. The rock is everywhere washing away, as shown by the undermined and fallen trees and pinnacles, but to the S.W. of the island is a considerable, probably growing, area of sand. Between Faidu and Difuri is a bight of water from the lagoon, 12 fathoms or so deep at its inner end; this appeared to run across the greater part of the reef, but the sea was breaking in a continuous line across its outer end on both the days I spent in this neighbourhood, so that any investigation was impossible.

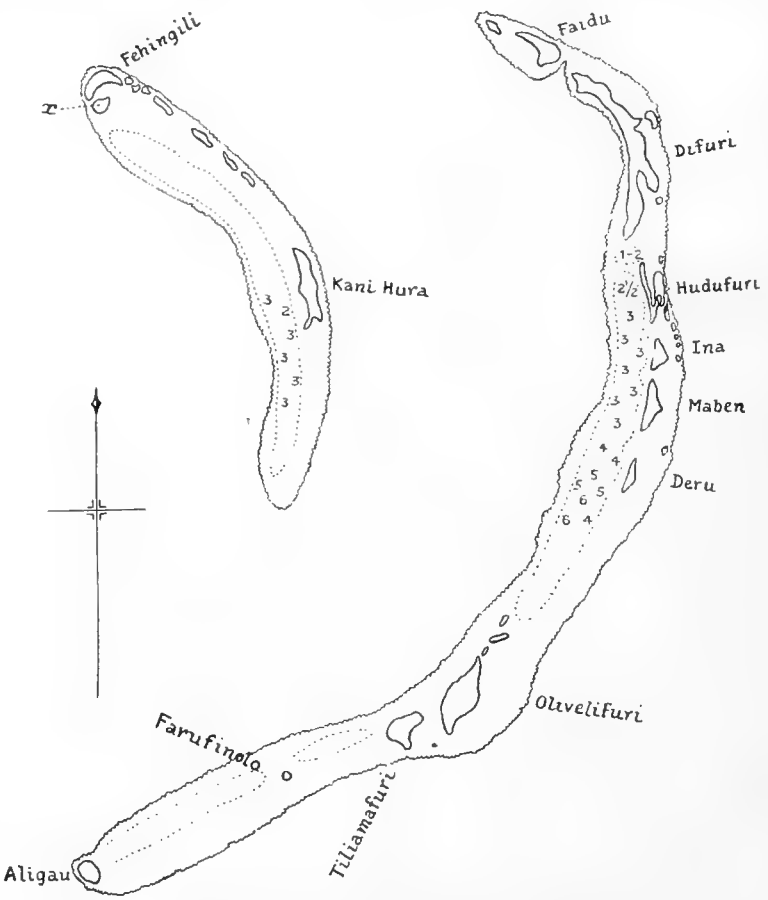


Fig. 104. Two of the E. reefs of Fadifolu Atoll much enlarged. Compare with Fig. 103.

The clump of islands of which **Difuri** is the northernmost forms more or less a double series, although some islands by extending into both lines join them. The outer line forms a series of nine small wooded islands, joined to one another by a series of rocks on the reef. These islets are all built of rock alone, and their outer shores lie about 60 yards behind the seaward edge of the reef. The second, or inner, series consists of three much larger islands, which are all composed of sand. These

islands do not reach to within a considerable distance of the seaward edge of the reef, on which side they vary greatly in shape. To the W., however, their shores form a line 500—600 yards behind the lagoon edge of their reef. Belonging to both the series are the islands Hudufuri and Difuri. The southernmost of these, Hudufuri, has a belt of rock right on the outer side of the line of rocky islands, joined by a narrow isthmus—formed by two deep bays to the N. and S. of the island—to a stretch of sandy land as decidedly belonging to the inner line. Difuri is less regularly divided, but a bay to the S. with for the most part rock outside and sand within indicates the two lines.

As to the changes going on there is to the E. of the rocky belt a marked washing away, which, continuing for some distance round the ends of the islands, has formed the deep bays in Hudufuri and Difuri[1]. There is also some slight washing away to the E. of the islands of the sandy line. To the W. of these same islands there is practically no change at all, but the ends of all these islands are growing out along the reef towards one another. Whether the islands themselves will ever meet is uncertain. They are at present separated by channels of 4—6 feet of water with very strong currents, a depth so unusual for such a position that it appears probable that the dividing channels increase in depth with their restriction in breadth, the two processes going on until equilibrium is established. The above, however, is not quite true for Difuri, which, while perhaps a little growing at its ends, shows a distinct washing away along its whole lagoon side.

From the N. end of Hudufuri to the Olivelifuri clump of islands a velu extends along the W. side of the reef. It is separated by a sand flat of about 90 yards in breadth from the inner line of islands, but opposite the channels between them this flat broadens considerably. Its depth varies from 3 fathoms to the N. to 6 fathoms a little south of Deru. As to its character it is quite open, and has a soft, sandy bottom. Life, both free-living and sedentary, is in it very scarce, the latter being only represented by a few coral knolls on the W. side and some small coral colonies opposite the passages between the islands. To the N., almost between the islands of Difuri and Hudufuri, is a separate small pool of $1\frac{1}{2}$ fathoms.

The lagoon reef is a flat about 50 yards broad—narrower to the S.—part of which seems to be awash at low spring tides. The whole way along it appears to be so even that a man could wade upon it at low tide from Difuri to Olivelifuri, and probably from the latter again to Aligau. Along the W. of Difuri it extends for about the half of the length of that island, thence further N. gradually merging into an area, where there is no true reef, but merely a number of isolated perpendicularly-walled reef patches with sandy ground—the slope of the Difuri shore—between. Against the lagoon the reef has no edge, but passes into an area covered with large, massive *Madrepora* and *Porites arenosa*. This again opposite the islands falls precipitously to the atoll lagoon, but in the open part to the N. of the Olivelifuri set of islands we found an area with 5—10 fathoms of water, covered with loose, dead coral masses, the dredges and swabs practically failing to secure any fixed life at all. To investigate this small bank would have required a residence for a considerably longer time in the atoll than we had to spare. We found no area elsewhere which could be in any way compared with it, and I am inclined to think that it is a formation entirely due to local causes. The currents of the N.E. monsoon would naturally sweep along the reef by the islands and across in the open space, clearing off any coral masses from the W. reef and depositing them inside. Further, the condition would be almost that to the W. of the long main island of Funafuti, where there is in the centre an extensive and increasing deposition of sand[2].

Off **Olivelifuri** I was unable to localize any fixed point of the reef to the S.E., the contour appearing quite rounded. The island is of sand alone, and no part approaches within 200 yards of the reef edge. All sides of the land except perhaps a sand spit to the S. show washing away. This

[1] These are inhabited by immense numbers of stinging rays, a fish which we saw nowhere else in the Maldive Group.

[2] *Vide* "The Coral Reefs of Funafuti, Rotuma, etc.," *Proc. Camb. Phil. Soc.* vol. IX. p. 435, 1898.

is best seen on the N. side, where two islets have been cut off within the last sixty years. Beyond these again arises a third little sandy islet, the only remains of the one shown in this position in the chart. To the S. a rocky mass stands on the reef much nearer its seaward edge, half-way to Tiliamafuri. The latter island is all sand, with one possibly stony point to the S., and is slightly washing away along its lagoon side.

Between Tiliamafuri and the tiny sandy islet of Farufinolo there is said to be a shallow velu, and beyond the latter there is certainly one to Aligau, which is mainly formed of rock, the reef closely fringing the land both N. and S. The three reef patches marked in the lagoon in this vicinity were all clearly defined, the one marked Maduwari alone being noticeably larger than shown.

VI. North Male.

My investigations in this atoll were confined to cursory examinations of the south-west reefs on our voyage to Goifurfehendu atoll and of the east rim reefs on our return to Male island from Fadifolu, and to a nearly two months' residence at Hulule and Male, when some of the islands and shoals in the vicinity were visited. Mr Forster Cooper also made an eight days' sounding and dredging cruise throughout the centre of the atoll.

I have little to chronicle about the North Male bank, which seemed to be in a very stable condition. All the rim reefs are well-defined on their seaward faces, even those to the south-west of the bank. Most of them, indeed all that are not merely small reef patches perhaps with land, are definite faro, including the reef of Immufuri and those to the north-east of Asdu. In the larger faro of the east side, the depths of the velu are very uniform, varying between $5\frac{1}{2}$ and 8 fathoms. All on the east side have well-formed reefs against the atoll-lagoon, except that opposite Mirufenfuri on the Difuri reef there was a break of about $1\frac{1}{2}$ miles with from 3 to 6 fathoms of water. Most of these velu of the east rim are bounded to the west by sand-flats, which decrease in breadth as their whole faro become of more perfect formation. They are not found in this position in the Difuri faro, nor in that next south of Helengeli, the velu of these last being separated from the atoll lagoon by mere rims of growing coral. The latter, indeed, bound all to the west, and consist of coral colonies, not consolidated together in any way, which at about 3—4 fathoms pass into a precipitous or almost perpendicular fall to about 20 fathoms, or to within about 5 fathoms of the general level of the lagoon bottom in the vicinity, the surface of this slope being almost completely bare of sedentary life. The characters of the reefs of the west rim of North Male are not so well-marked, but most are definite faro, some of which are very imperfect in their eastern or lagoon reefs.

The reefs within the North Male lagoon of more than half a mile in diameter, that are marked in the chart, appeared to be all definite faro, though some, such as that on which the island of Barosse is situated, with shallow velu—only perhaps 1 or 2 fathoms deep. Our dredging, the lines of which must have covered about 75 miles of the bottom, failed to find any definite coral patches or reefs growing up, the surface of the lagoon floor being almost flat between the different shoals and covered with coarse or fine sand. Inequalities existed, it is true, but these did not seem more favourable for coral life than the deeper parts. Some of the reefs appeared to have enlarged to a considerable extent, while of others we could find no trace of their former existence. Many showed a marked trend along the direction of the currents, which would cross the atoll. This was particularly the case near

Barosse, but it was quite impossible to reconcile the existing reefs in this neighbourhood with those drawn in the chart. Some seemed to have become joined together, while others had bodily shifted their positions—or fresh ones of large size had grown up—and yet of still more no trace could be found.

On the whole the changes in North Male lagoon were so great, and beyond our experiences in other parts of the Archipelago, that I could only conclude that they were either due to so-called "corrections" of the original chart, or to difficulties that we know to have existed in making the first survey, and which would necessarily have been very great nearest Male, the Sultan's island. Owing to this, with the insufficient means at my command, it did not seem to me worth while examining the area, as otherwise I had intended. I may, however, remark that in my opinion, in which my companion concurs, this was the only part of the whole Maldive group that we saw, where there could have been any such inaccuracy in the original survey. Indeed, the south half of North Male atoll for this reason, and also in the interests of trade, all vessels entering at Male island, demands to be resurveyed in a proper manner.

With regard to the land five fresh sand banks were seen by Mr Forster Cooper between Male and Hembadu to the south-west of the atoll, all on inner reefs, while two islands of the east rim were found to have been washed away. All the islands within the lagoon and most of those of the rim are of sand. Where within the lagoon the island covers the most of its bank, such as Wagrenfaro, Hefuri and the two Bundusi, there is no living reef, and the island is washing away, whereas, if there is a large reef or faro, loss is more than counterbalanced by gain. None of these inner islands show any signs of elevated rock, and it is probable that all owe their existence solely to the piling up of sand from the atoll lagoon. The same seems to be true of most or all of the islands on the western rim, but on many of the east rim reefs elevated rock is found behind which the sand, forming the larger areas of the several islands, was probably by the same means heaped up. This was particularly the case off Hulule, where between the boulder zone of the reef and the island a series of masses of the elevated rock was found on the sand-flat. Their position here about 30 yards behind the boulder zone shows the former extension of the land, and also points to a considerable outgrowth of the reef to seaward, sufficient at the least to have formed the reef-flat since the original elevation took place.

VII. South Male, Felidu and Mulaku.

I have very little to record about these banks. They show remarkably little change in the contours of their reefs since the original survey was made. Some islands have formed, while others have washed away. As on other atolls the rule on the east rim is a washing away at the seaward ends of the islands, bounding, or off, which elevated rock is commonly found. There is a tendency for the formation of fresh islands—mostly at present mere sand-banks—along the encircling reefs, wherever they extend in a more or less east and west direction. The most remarkable example of this is the Hurasfinolo reef in South Male, to the north of which five such banks have formed. On the whole there is curiously little land to the north and south of these atolls as compared with others in the group, and this is still more especially the case on the west side, particularly when considered in conjunction with the more perfect atolls to the south. Such land as there is on the latter side is mostly

formed of sand; a few rocky banks, it is true, do occur, but most of these are obviously piled up by the waves, and there are extremely few, if indeed any, pinnacles, undoubtedly belonging to the elevated rock. Fresh islands and sand-banks are not infrequent on the west side, and probably all the land in this position has been formed by the heaping up of sand. Further, the relatively small reef patches which form the west rim, as compared with the east, are remarkable, everything in conjunction pointing to a much less perfect condition of the west side as compared to the east, when the original elevation, that formed so much of the land of the Maldive banks, took place.

My companion, Mr Forster Cooper, who investigated the lagoons of these atolls by soundings and dredgings, reported singularly little change in them. The depth nowhere had decreased, but an increase was rather indicated, though on account of the difficulty of accurate fixation it was impossible to afford definite proof of the same. Most of the larger interior reefs are faro, and even smaller ones of 150—200 yards in diameter have the centre rather lower. None definitely showed growth. All have precipitous slopes with an area of decaying coral masses around them.

Only ten passages into the different lagoons were examined, in three of which distinct shoaling was found. In seven an apparent constriction seemed to be taking place by the outgrowth towards one another of points from the neighbouring reefs. Upgrowths of new shoals near the inner ends of two passages occurred, a most unusual feature at the present day. No areas, covered with living corals, such as might form shoals, were met with in the interior of the banks, but isolated massive colonies of *Goniopora* and *Alveopora* were frequently dredged, and some parts were much covered with the living and dead coralla of the solitary *Diaseris*. *Dendrophyllia*, which of all the corals was most frequently dredged in the living state, seemed for the most part to be confined to passages and current-swept areas.

VIII. North and South Nilandu (Fig. 105).

I cannot do more than call attention to a few points in these two atolls, which in their topography are intermediate between the more open banks and the more perfect rings of the Maldives. The characters of both banks are so admirably shown in the charts that it is only necessary for me to refer to the shoals within their lagoons. These in different situations show in their characters every grade between the similarly-situated reefs of Miladumadulu and those in the most enclosed parts of Suvadiva or North Mahlos, from reefs that are indubitably growing outwards to others that are as certainly being removed by solution and other agencies. All the shoals on our course seemed to be correctly placed in both atolls, but in the south of the northern atoll we found in addition six uncharted shoals and three others in which growth was particularly strongly marked. Most of the shoals within the encircling reefs of the atolls were represented in the chart as presenting flat tops without land. All over 200 yards in breadth that we examined—twelve in number—in addition had velu, definite little lagoons (Fig. 105), whereas a central pool was only charted in a single one. In the southern atoll the same prevalence of velu was noticed, and indeed their presence in all the larger shoals of either atoll appears to be the rule. Beyond this a considerable enlargement was found in all the charted velu that we passed, whether in the lagoon or rim reefs.

The above facts appear to me to be of considerable significance as bearing on the formation of lagoons in general, treated of more particularly in my Chapter (VI.) on North Mahlosmadulu bank. It seems to me to be nearly impossible to believe that there is any error on my side, or on that of the original cartographers, by which the above changes can be explained. The charts were in the first place so carefully made, and pools of deep water, wherever present in the lagoon reefs, so carefully charted on other banks that North and South Nilandu —and probably also Ari—give the strongest support to the view that atolls can be and are commonly formed by the spreading outwards of surface reefs and the solution of their central parts. I believe that owing to the shallow depths of their foundation flats, their protected situations and other peculiar conditions the lagoon reefs of these two Nilandu banks show, even in the odd 64 years since the charts were drawn, the change from a flat reef to a perfect atoll. In their entirety, too, these lagoon reefs give a complete series from the smallest reef, a single coral head—perhaps only a single coral colony—to an atoll a mile or two in diameter.

A point, everywhere observed in the Nilandu atolls, was the decreased breadth of the lagoon reefs, which separate the velu of the rim from the lagoons of the atolls. All the rim velu had increased in size, and, while much of this was undoubtedly due to growth in length, yet more would seem to have been caused by increase on their lagoon sides. The lagoon reef of any velu in the rim of either atoll is generally perfect, but it is only a thin line, 40—60 yards across, covered over the greater part of its breadth with living corals. It differs among other points from the reefs to seaward in never having a boulder zone and in not being backed behind—and so separated from the velu—by a sand flat of a quarter or half a mile in breadth, such flat, if present at all, being

FIG. 105. North and South Nilandu Atolls (*considerably altered from the Admiralty Charts*).

seldom more than 30 yards across. In the lagoon shoals also a similar narrow breadth of the reefs round the velu, where no land of any sort exists, was also observed. The solution where the reef is protected, eats up almost to the growing coral layer, and, if any accident befall these animals so that they die, it is easy to perceive how that the water of the velu and of the atoll-lagoon will quickly eat a passage through the reef, and join one another. In this connection the south-west reef of South Nilandu is most noticeable, as it appears to have had a long linear velu, which has now become joined to the lagoon of the atoll, leaving, nevertheless, a series of isolated reef masses, parts of the original great breakwater.

The land of both atolls is nearly all built up of sand, and there are many fresh banks of the same formed on reefs in the lagoons, though it is doubtful whether many—or indeed any—of these will ever form islands, covered with timber. The changes in the land are mainly local, depending on the passages, etc. in the immediate vicinity of each separate island. No signs of pinnacles of elevated rock were observed, and it is possible that the elevation, such as it is in the Maldive region, had no part in the formation of the land that exists in either of these atolls[1].

Within the lagoons no changes in depths were found. The bottom in most places is of hard rock or sand, and in South Nilandu its fauna was richer than on any other bank in the group. Indeed six dredgings in this atoll yielded as great a variety of animals as any consecutive eighteen elsewhere, and the number of specimens of some of the species of Crustacea, Echinoderma and Mollusca was extraordinary. Of the passages into the lagoons only those we traversed in going into and out of each atoll were examined. That of Maimbudu was found to have a shoal of 7 fathoms in its centre within a few yards of the 40 fathom line, the steep of the reef commencing from the shallowest water of the channel. In Mawafuri passage three shoals, almost reaching the surface, were found.

IX. Kolumadulu and Haddumati[2] (Figs. 106 and 107).

These atolls resemble one another closely in that they have single and relatively perfect encircling reefs, enclosing large lagoons with 40—45 fathoms of water. The lagoon shoals of each are comparatively small, although fairly numerous, with the regular, almost perpendicular cliffs usually found around them. None have land, unless situated close to large passages into the atoll lagoons, and none are faro. Both have for the greater part of their circumference single rather narrow reefs, without pools of water in the centre. Both are exposed on the east and also on the west to the full force of the sea, and on the other sides are afforded little or no protection by the neighbouring banks. Lastly the land in each is mainly situated to the south and east, in some positions consisting of lines of islands almost joining one another, while to the north and west the reefs are very bare.

The islands are for the most part formed of sand alone, and, as a general rule, are to seaward bounded by a well-defined sand flat, boulder zone, and reef flat. A few, however, send out heads as far as the boulder zone, and these are generally washing away at their ends. Behind, their necks are usually being cut through so as to separate the rocky outer

[1] That this is really the case is, however, distinctly unlikely. Our time was too short to enable us to stop and examine the individual islands, and our attention was mainly taken up with the almost universal faro formation of the shoals.

[2] My knowledge of these atolls is confined to two hurried visits in the s.s. *Ileafaee* in going to and from Suvadiva. In addition Mr Forster Cooper spent 10 days in Kolumadulu and 8 in Haddumati, dredging and sounding the deeper waters of their lagoons.

ends from the larger sandy inner areas, and in many places isolated islets, or rock masses, so formed are found in or just behind the boulder zone. Most islands are separated from the atoll-lagoons by broad flats, and in but few are definite changes of any sort indicated on this side. The sandy islands commonly show a slight washing away on their seaward faces with often, where many islands are present, a growth of spits towards one another, or, if an island be isolated, along the reef. In some places, too, sand-banks have formed on the reefs, and here and there an island seems to have been completely removed. The most marked change was seen at Fahala in Kolumadulu, to which has become joined the small island to the north. The south end has on the contrary been completely washed away, and in its place

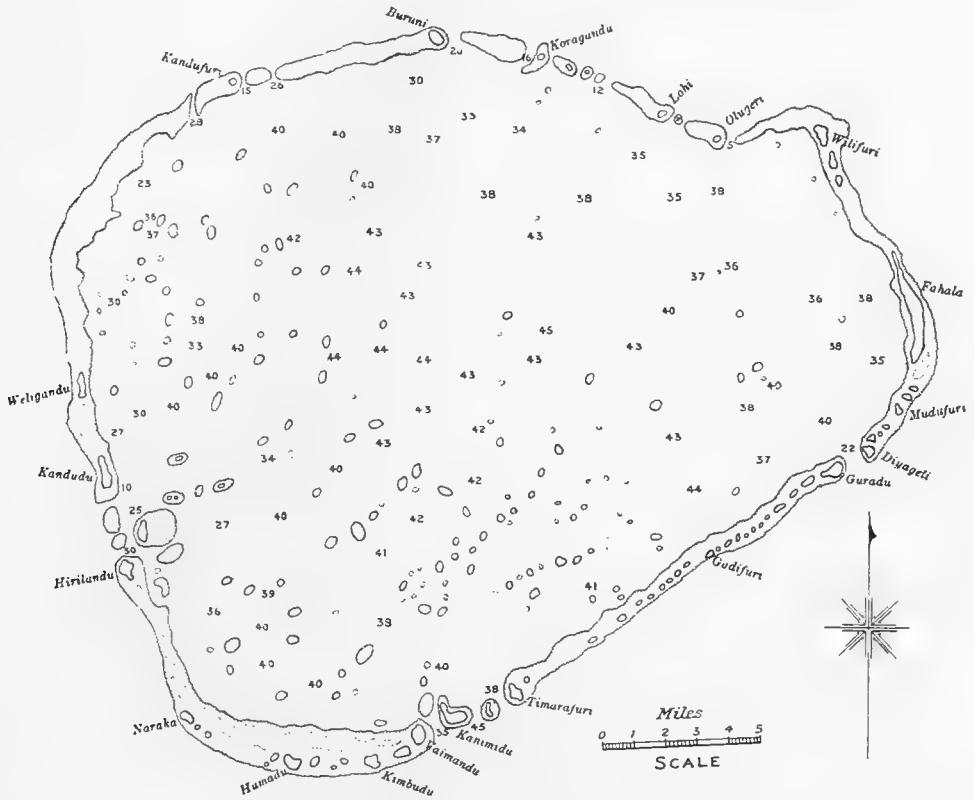


Fig. 106. Kolumadulu Atoll (*a little altered from the Admiralty Chart*).

is a double velu in the centre of the reef, the largest and deepest part to the E. Further south the next seven islands mostly have to the east rocky points, which are being washed away, while the sandy parts behind are growing out along the reef towards one another, so that the south four have nearly fused. Isdu in Haddumati sends out a point to the boulder zone north-east and another north-west, both of which are probably outgrowths, while the north end of Dambidu has been cut off to form a fresh islet. The latter has also taken place at Funadu, but the second island north of Ghang has been washed away.

Within the lagoons of both atolls a mixture of sand and mud is found, covering the bottoms, on which a few Mollusca and Crustacea alone live. In some places there is a covering of low green algae, and in others horny or siliceous sponges. Mr Forster Cooper nowhere recorded a determinate change in depth, nor did I find any in a close-set line of

soundings between Guradu and Buruni in Kolumadulu, nor in isolated ones from north to south in Haddumati. The vast majority of the shoals that we fixed were found to be as marked in the chart. Mr Cooper, however, observed that several, which were represented as reaching the surface, only existed as mounds well below the low tide level. In passing through Kolumadulu, too, I observed that a few presented in the sunlight a dark, blackish appearance—a contrast to the vivid brightness of a growing reef. Two of these near the north of the line between Guradu and Buruni I crossed, finding both completely submerged and apparently quite dead, being covered by fine mud with no living corals.

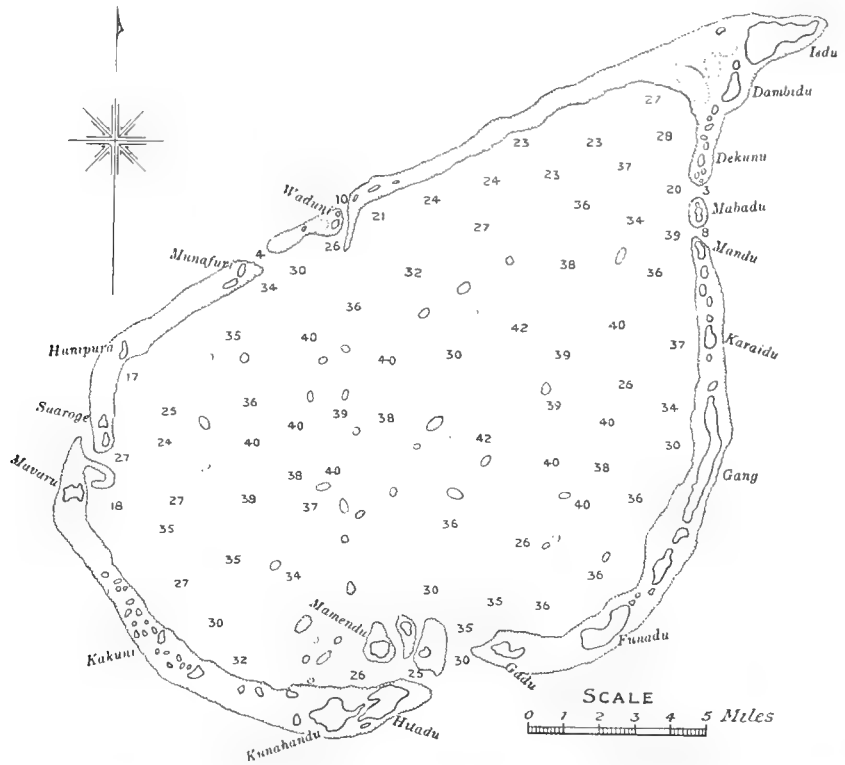


FIG. 107. Haddumati Atoll (*slightly altered from the Admiralty Chart*).

As far as the passages were concerned, I only examined four, and found changes in all. This was remarkable and probably due to the fact that all four were among the largest in either atoll. In Kolumadulu the Buruni reef had grown out somewhat to the north-east, its south-east horn seeming in addition to have been somewhat cut away, and the Guradu passage had narrowed near its seaward end by reefs growing out into it from either side. In Haddumati the Munafuri passage has as least depth in its centre 4 fathoms (seven soundings), but it differs from the Guradu one in having very distinct outgrowing horns towards its lagoon end. The Gadu channel is constricted by an outgrowth of the Gadu reef to the west, and by that to the south of both the reefs between Gadu and Mamendu, the Hitadu reef showing no changes.

X. Suvadiva Atoll (Plate XXI.).

Suvadiva is such an immense atoll that it was scarcely possible to see sufficient of it, even in five days, to venture on any conclusions as to its formation and origin. It is really an isolated bank by itself, separated by broad channels from the other parts of the group, in which Prof. Agassiz found 1130 fathoms towards Haddumati and 1292 and 1048 fathoms towards Fua Mulaku and Addu[1]. A vast contrast in size to the latter and to the northern banks of the line, Suvadiva, among the whole area of the Maldive and Laccadive groups, is only comparable in a small degree to Haddumati, between which and Kolumadulu Prof. Agassiz found 1118 fathoms. A better comparison would be with the Great Chagos Bank, which might well represent an incipient stage of such an atoll as Suvadiva.

On account of its great size, deep foundations, almost perfect rim, and large, open, and relatively deep lagoon, it is necessary on almost any theory of the formation of atolls that has been propounded, to assume for Suvadiva a greater age, a longer period of time since its foundations were laid, than is necessary for any other bank of the Maldives and Laccadives. With increased perfection of shape, too, the difficulty of deducing the stages by which the whole was produced, increases very greatly. Recognising that there is much which can only be understood by the analogy of other banks, I here merely draw attention to the changes and conditions which seem of general applicability to the whole atoll, before passing to a somewhat more detailed account of the parts I visited, than I have thought it necessary to give in respect to the other parts of the Maldives.

The land exhibits the usual changes found elsewhere, in some parts showing loss and in others gain. The reefs everywhere to seaward have the typical outer slope, reef-flat and boulder zone. The latter is formed entirely of loose masses of rock, the skeletons of corals and other reef organisms, fragments off the reef outside, and sometimes blocks of a consolidated rock, that now lies above the low tide level. Some of the islands have to seaward a belt of rock and there are also found isolated masses and pinnacles of the same on the seaward reefs. Much of this rock shows its origin to be due to elevation, but no definite pinnacles are found in the boulder zone, so that it is probable that the whole, or a considerable part, of the breadth of the latter and all that of the reef flat have grown out since the elevation took place. The raised rock is being eroded away, but loss at the present time is being balanced by gain, though it is certain that the land once formed a much more continuous, if considerably narrower line, upon the encircling reefs. Along the lagoon sides of the islands there is in places loss, but it is not general, the reefs being usually broad and in some parts seeming to be growing out. The latter, however, is only the case in the more open parts of the atoll, the opposite conditions prevailing to the S.W. Some of the reefs round islands within the lagoon are growing out in places, but the islands themselves with very few exceptions are gradually but surely being washed away.

Points of the reefs, extending out into the lagoon by the mouths of passages, might conceivably grow round in time to meet one another, and by fusing form velu in the rim. I could, however, find no sign of their doing so, or having done so, while on the contrary such velu as there are in the rim, are gradually being put into connection with the atoll lagoon. Some of the shallower passages are undoubtedly being closed up, both by the growths of organisms on their bottoms and sides and also by the pushing out of points against the

[1] "An Expedition to the Maldives," *Amer. Jour. Sci.*, ser. IV. vol. XIII. p. 301 (1902).

sea from their bounding reefs. The deeper passages, although they literally teem with animals, seem neither to have shoaled nor to have been at all constricted.

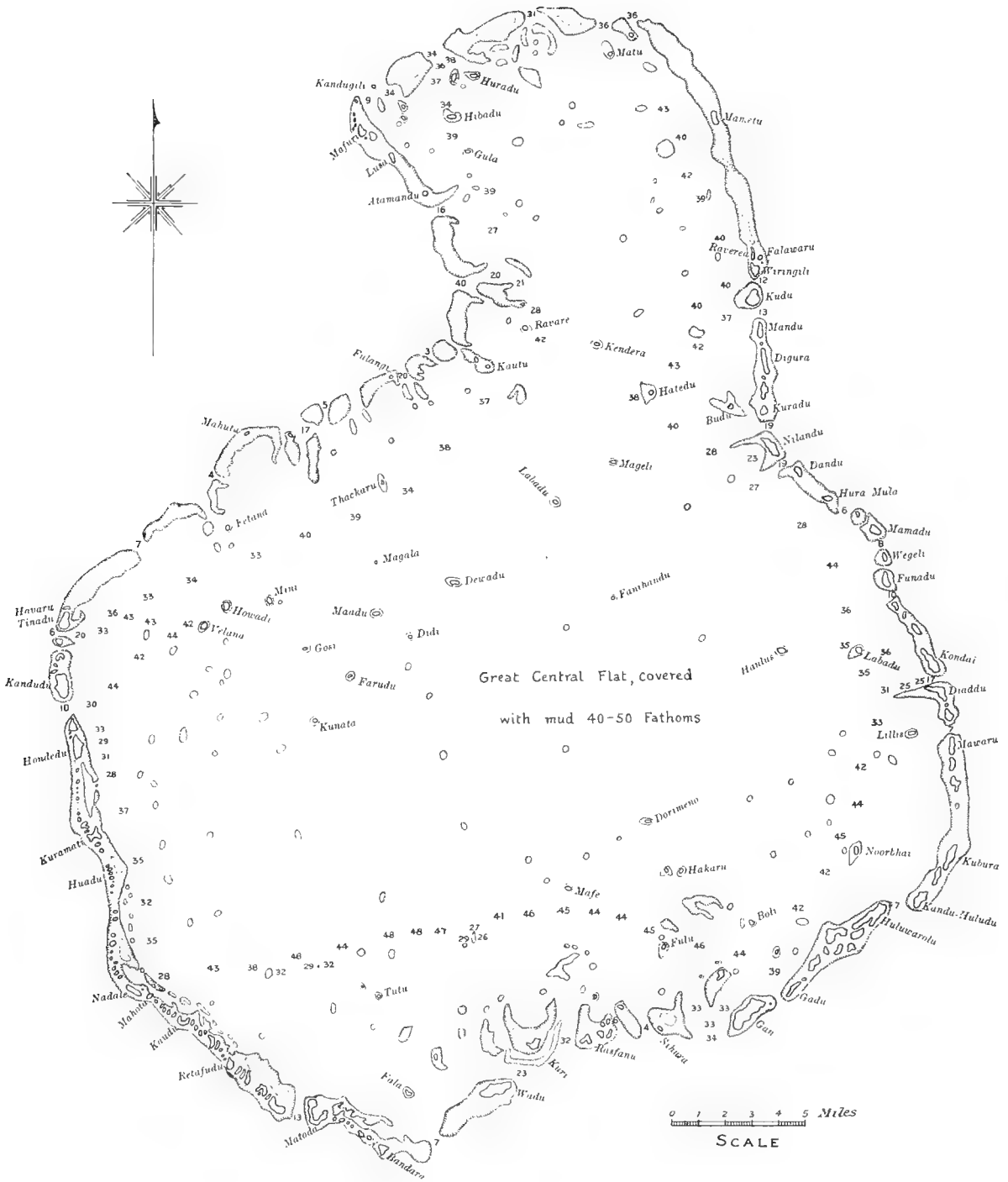
The lagoon is remarkably uniform in depth, and its bottom except near passages is everywhere coated with mud, to which I have already referred in Appendix A, Sec. II. "On the Formation of Lagoons." The shoals to the south and west of the lagoon, and to the east with a few exceptions, viz. those which have been referred to with growing points, have precipitous slopes from about 4 to 30 fathoms with very narrow rough areas around, strewn with dead masses from the flats above. Among these sedentary reef organisms do not grow, while every stone is riddled with boring animals, and very quickly destroyed. It is impossible for the larvae of sedentary animals to become affixed on a muddy bottom, and there is no piling up of sand anywhere, so that what change there is in the lagoon is likely to be one of loss rather than gain, an action possibly shown by an increase in depth, found especially towards the south part of the atoll.

Matu and the island opposite to it on the other side of the passage are both of coarse sand, and covered with tall coconut trees. There has been a little loss to the E., but there is no marked change. I could not find the shoal shown to the E. of Matu, but all others and the depths as far as Wiringili are as represented. The island to the N. of **Mametu** has disappeared, and to the S. of that island the reef has a narrow velu, extending along the whole of its length. To the E. of it in the centre are two rocky masses, standing on the sand-flat behind the boulder zone of the reef, their summits a foot or two exposed even at high tide.

Wiringili is mainly formed of sand and occupies the S. end of the reef. Its lagoon-reef is rather low, no part being exposed at low tide, and the shore, 200 yards behind its edge, has a few fallen coconut trees but no signs of extensive loss. To the S. the island is fringed with an area of coral rock, the beach lying on the inner edge of the boulder zone. The latter and the reef-flat merge round the S. of the island into the reef of the W. side, while the island sends out on it to the S.W. a stone-covered spit. On the east side the rock has been pierced, and the beach washed back from the boulder zone. The channel between is now a bare, smooth flat, covered with low green algae, but four lines of the beach rock show stages in the former washing away. The boulder zone appears to be entirely a recent formation. The two sandy islets of **Raverea** are now joined, and the single island formed is sending out a sand-spit to join one that has grown out from Wiringili. **Falawaru** lies just inside the boulder zone and is formed mainly, if not entirely, of coral rock. Its former connection to Wiringili is shown by a mass of rock halfway between it and the rocky outer end of that island. A few rocks to the N. indicate a considerable former extension of Falawaru along the reef towards Mametu, rock masses showing at the least a series of islets.

The slope from Wiringili reef to the lagoon is very gradual in its greater depths. An edge is clearly defined at about 1 fathom, soundings giving 20 yards from the same 11 *f.*, 30 yds. 12 *f.*, 40 yds. 14 *f.*, 70 yds. 19 *f.*, 90 yds. 23 *f.*, and 100 yds. 28 *f.* At 11 *f.* the bottom had growing on it between large, bare, sandy areas, a few small spreading colonies of *Montipora* and *Madrepora*. The reef edge is covered with coral growth, but the colonies as at greater depths are not of large size. There is plenty of variety but no luxuriance, and the quantity of weed present is extraordinary for such an area.

The channel separating Wiringili from Kudu has only 13 fathoms instead of the 15 marked, the soundings across from Wiringili at even distances giving 13, 13, 13, 13, 13, 13, 13, 12, 12, and 11 fathoms. **Kudu** is all sand except for a rocky point to the E., 20 yards behind the boulder zone. Opposite the middle of the island a point runs out from the reef into the lagoon



SUVADIVA ATOLL.

(Soundings in the lagoon by the Expedition.)

To face p. 411.

for a distance of about 1 mile, the greater part a sand-flat. The channel to Mandu is considerably broader than that to the N. of the Kudu reef, which seemed correctly charted.

Of the lagoon islands **Kendera** is sandy with low shrubs, and **Mageli** and **Labadu** sandy with tall coconuts or other trees. **Hatedu** shoal is much enlarged to the W., and appeared to enclose a small shallow velu; the island, which is of sand with low bushes and a few coconut trees, is washing away on the W. side. The **Budu** reef has grown W.N.W. and E.S.E., a shoal in the latter position having become joined up to it. The passage to the S. of **Kuradu** appeared narrower than in the chart, and we could find no shoal as therein shown.

Nilandu is a sandy island, at present changing very little, situated about 250 yards behind the seaward edge of its reef, on which the boulder zone is, as usual, clearly defined. The seaward shore has much rock, and a few bushes are undermined; lines of the beach rock show that the land once extended at least 120 yards further E. on its sand-flat. The passages, both N. and S., are much reduced in size, the latter by an outgrowth of Nilandu reef. Two horns from the reef, too, have extended out considerably into the lagoon at right angles to the general contour of the rim, and there is a velu with 5—6 fathoms on the S.W. side of the island. Of this there is no trace in the chart, the positions of the soundings on which most decidedly point to its non-existence when the survey was made. The lagoon reef is ill-defined, and has in most places 1—2 fathoms of water with a wide opening to the S., only an odd coral mass here and there reaching the surface; off it the slope is gradual, with bare patches of sand. The velu itself has little coral growth, but there is a fairly marked line of *Goniastraea* and *Porites* colonies against the woody sand-flat of the island.

Most of the islands on to Kondai, our next halting-place, are eroding on their lagoon shores but there are no marked changes in either land or reefs. **Dandu** reef is as shown, but the shoal off the same is situated further to the N.; the island is of sand with rock to the E., and has fused with the next island. We could see no trace of the southern of the two passages between **Mamadu** and **Hura Mula,** and the N. one had broken water right across its centre, indicating an upgrowth; the S. reef of the latter passage too has sent out a very distinct point to the N. The three channels between Mamadu and the Kondai reef were all clear, but the waves occasionally broke across the central one. All the islands had tall coconuts, but the four islands N. of Kondai on the same reef had been reduced to three by the fusion of the two southern.

Kondai is a sand island with a little beach rock to the S., above which is found a cliff of 3 feet and a few fallen shrubs. All loss is on the S. and W. sides, the island being protected by its broad reef to seaward. Due E. starting from the broad sandy beach of the island is a sand-flat, 250 yards across. The first 60 yards of this is covered with sand and weed. The area from 60 to 120 yards from the beach is almost a solid flat of dead *Heliopora*, just covered at low tide; a few colonies, however, were found to be still living towards the outside, where the zone merges into a rougher area continuing out to 210 yards. This has about $1\frac{1}{2}$ feet of water, and is a flat with much dead and rotting coral, in addition to low living colonies of *Porites arenosa*, *P. palmata* and *Pocillopora suffruticosa*, *Madrepora* only commencing towards its outer side; weed is scarce but there is much sponge-growth and many Holothurians. The bottom now, 210—250 yards, slopes up to the boulder zone; living colonies of coral become scarce and weed commences, but there are many large, decaying masses of *Porites arenosa*. The masses of the boulder zone are small, and lie loose on a solid, smooth rock-flat, the inner part of the next area; on the whole the zone is ill-defined, and is broken at about every 70 yards by channels, through which the sea rushes on to the sand-flat. Beyond this again lies the reef-flat, which is much pitted for 20 yards out and almost bare. In the next 30 yards to the reef edge colonies of *Madrepora*, *Prionastraea*, *Montipora*, *Leptoria*, *Astraea*, *Orbicella* and *Goniastraea* were identified. Fissures run in for 20 yards, but they are about

40 yards apart, and always have sloping—not overhanging—sides. At the edge, where there is a small precipice of 2 fathoms, only nullipores were found. The reef outside slopes gradually, the bottom for about 60 yards being quite visible and covered with living corals.

The enormous quantity of *Heliopora* is very remarkable, quite a large area of the sand-flat being covered by it, and without parallel on any reef that I have seen, in the Maldives or elsewhere[1]. Doubtless it is due to the denser skeletons of these Alcyonarians resisting the decay brought about by organisms better than the Madreporaria, the dead corals of which were all much rotted on the same area. The variation of the character of the reef edge compared with more northern atolls is noticeable, particularly in the fissures having sloping, not overhanging, edges.

The seaward reef merges round the S. end of Kondai into the lagoon reef, being about 120 yards distant at the S. point. The lagoon reef has the characters previously described off Wiringili, but its edge is very irregular, and much of the bottom off the same is covered with sand.

Hanlus, Labadu and **Lillis** islands are all sandy and covered with low bushes. The only change was seen in an outgrowth of the reef of Labadu to the W.S.W. The islands of **Diaddu** reef are likewise all sandy with spits along their reef. Diaddu island and reef both show an outgrowth towards the lagoon. **Mawaru** and the island to its S. are joined, as indeed nearly are the next pair on its reef. The reef of the sandy **Noorbhai** island has extended out to the S. and there has appeared a small shoal to the E. The reef from **Huluwarolu** to Gadu has a double set of islands, the eastern formed partially of rock, but the western composed entirely of sand. The latter are extending out towards one another, and one has already become fused up to Huluwarolu. The two islands next N. of Gadu have very extensive formations of beach sandstone on their seaward sides.

The seaward or E. reef of **Gadu** is similar to that off Kondai, but there is no *Heliopora* zone and less dead coral; the boulder zone also is more conspicuous. The land behind shows a little erosion, and there are lines of beach rock on the sand-flat. The island is only built up of stone to the S., and this part consists principally of pebbles, which have become consolidated together; inland may be traced the lines of three former beaches, showing how the land has been extending outwards on its reef. The beach against the passage almost runs on to the boulder zone, which has towards its inner part a definite line of elevated coral masses, now much undermined. The inner flat in this part, wherever it exists, is peculiar in that it consists of bare rock with no sand. The reef also has right round its edge a crest absolutely similar to that at Rotuma[2], an equal development not being found by us elsewhere in the group. The boulder zone further extends right round to the lagoon side, where the edge of the reef almost reaches the surface, thence falling almost perpendicularly to the floor of the lagoon.

It is difficult off Gadu to trace the line of the original elevation, but the land probably never extended out to the E. as far as the present boulder zone. In this position there is a line of coral pinnacles about 90 yards behind the reef edge, 40—50 yards within the boulder zone. This continues as far as the eye can see to the N., and, if it be taken even as the inner end of the original raised reef, would show an outward growth for the present reef of at the least 70 yards since the elevation took place.

The waves during our visit to Gadu were occasionally breaking right along the whole distance to Gan, the passage seeming much narrower than shown on the chart. **Gan** itself is quite similar to Gadu; its reef has grown out to the N.E., and there is a stone heap in this position on the boulder zone. The island shows marked loss on the S.W. side, but N.W. the lagoon-reef is only

[1] It compares only with the raised *Heliopora* reef, described at Funafuti by Professor Sollas in *Nature*, vol. LV. p. 376, and referred to by me in *Proc. Camb. Phil. Soc.* vol. IX. p. 422 (1898).

[2] "The Coral Reefs of Funafuti, Rotuma, etc.," *Proc. Camb. Phil. Soc.* vol. IX. p. 442 (1898).

50 yards broad. The lagoon islets in the neighbourhood are all sand heaps covered with bushes, their shores giving signs of more or less considerable loss.

From Gadu we went almost due W. to Nadale, putting down 25 soundings on the way. All these showed an increased depth as compared with the chart, varying from 1 to 6 fathoms. They contrast with those of the E. side, where the depths were all about the same as recorded. Indeed, there appeared to have been a real difference, an actual average increase of about 2 fathoms in depth along our line. The bottom was everywhere coated with mud, except in the immediate proximity of shoals. The latter along our course were all located, and appeared to be smaller, but no accurate observations or comparisons were possible. The lagoon islands all showed washing away, but the process evidently is not very rapid. With regard to the southern encircling reefs there is a marked tendency to velu formation, but most of the enclosed pools are stated by the natives to have formed one or more communications with the lagoon of the atoll.

The islands immediately to the S. of Nadale show varying degrees of washing away on their lagoon sides. To seaward all run out into points, formed of coral rock, which are separated by some breadth of sandy boat channel from a continuous boulder zone. All have towards one another points of mixed sand and stone, apparently growing out to join the whole line together. **Mahota** thus is almost a rhombus in shape, the two acute-angled points to seaward and lagoonward, and the two other angles towards Nadale and the S. Erosion is taking place on **Nadale** both towards the sea and the lagoon, but the former is very slight, the beach being formed of coral rock. The latter forms a belt 100 yards broad, but does not seem to have ever extended out as far as the boulder zone, the reef-flat having been formed by the outgrowth of the reef edge. On the lagoon side the water has broken through the sand into a kuli, which formerly seems to have occupied the centre of the island. At its entrance is a small sand islet with three coconut trees.

On its lagoon side Nadale has a sand-flat, noticeable for its enormous quantities of sand-feeding Holothurians and Polychaets. It is about 400 yards broad, and ends abruptly with large clumps of *Madrepora* against a velu full of coral patches, 8—12 fathoms deep. These masses increase in size towards the lagoon, and are characterised by their perpendicular, or overhanging, sides, built up of such massive genera as *Goniastraea* and *Porites*. Some are so large that their centres are bare, or even slightly hollowed out, and quite dead. The E. reef is well-defined and likewise arises perpendicularly from the velu, but towards the atoll lagoon the bottom is visible for 150 yards, covered with great areas of *Madrepora* and *Lobophytum*. The velu appears to stretch S. as far as **Kaudu,** sending small bays out towards the sea between the different islands, and communicating freely with the lagoon. To the N. the velu continues for about 2 miles, but then its enclosing reef gives place to a series of isolated shoals, a small velu only appearing again to the N. of **Huadu.** This change is evidently due to the breaking up of the reef, the original line being clearly shown by the regularity of the line of shoals.

The islands from Nadale to **Hondedu** have all sandy beaches on their lagoon sides, exhibiting little or no signs of erosion. Their seaward ends have rocky shores, and reach generally to the boulder zone, which is well-marked; change is all in the direction of loss rather than gain. Between the islands on, or inside, the boulder zone is a series of coral masses awash, which indicates that the land formerly extended in an unbroken line from Hondedu to at least **Kuramati.** The latter island is interesting from its dumb-bell shape, two heads against the lagoon and sea, joined by a narrow bar, either side of which is strewn with timber. This is peculiarly interesting, as showing how the removal of the land may take place from the middle of a reef outwards. It bears also on the meaning of the presence of a double line of islands on the encircling reef, as found further N. by Hondedu, and on the E. side between Gadu and Huluwarolu. Sandstone masses lie quite on the lagoon side, indeed almost on the edge, of the reef by Kuramati, Hondedu, and the other islands to the N. It is accordingly probable that land once covered the whole of the lagoon reef in this

vicinity. A further change between Kuramati and Hondedu is seen in the fusion together of all the velu in the reef to form a single large pool. An entrance of about a mile in breadth has opened, however, into the lagoon, considerably broken by coral patches, the remains of an originally-continuous reef against the lagoon.

Havaru-Tinadu can best be seen in the accompanying map (Fig. 108). As it differs so materially from the shape shown in the chart, it is almost certain that there have been great changes. It would seem that the sea has eaten through the outer line of rock and cut into the sand, making a deep bay to the W. The loss is shown in the N.E. angle of this bay in layers of beach sandstone sloping to the W., stretching out from the shore upon the sand-flat. The action of the wind is well seen in a belt of sand, having been blown up for 6–7 feet above high tide level at the bottom of the bay, while the height of the island eastwards is only 2–2½ feet. This ridge averages about 45 yards broad, and passes round the bay into the rocky points. The latter on the beach show a solid coral rock covered with stones.

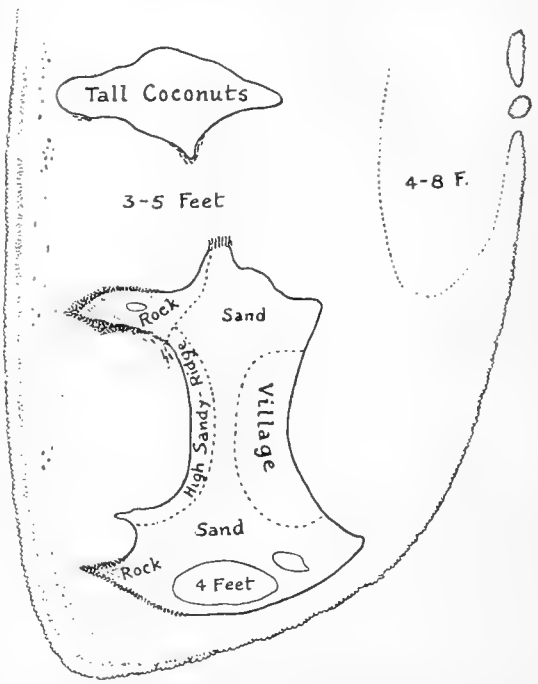


Fig. 108. Havaru-Tinadu (S.) and Mahuta (N.) Islands (*from a sketch map by the author and Capt. Molony*).

The W. bay is remarkable, in that the sand-flat below is covered all over with weed, and near the points strewn with rock masses. The beach is broad, and shows little sign of erosion, or of any other action at present. The sandstone, however, forms a sure indication of its former position, and shows clearly that the action is one tending to cut the island in half. There should be though, if the loss is one of quite recent date, a line of rock masses joining the two W. points within the boulder zone, but only a few small ones exist. On the lagoon side a shallow bay appears to have formed, but whether this is due to washing away, or not, I cannot say. There is no trace at the present time of loss, but rather if anything a washing up of sand on and around the S.E. point[1]. Indeed it is only at the seaward points and around the ends of the island that there is at present any marked loss going on, but even here the action is in most places inconsiderable.

Mahuta and Havaru-Tinadu would once seem to have been separated from one another in the same way as the latter is now being cut in half. Their former connection is shown by a series of sandstone masses—sloping towards the lagoon—extending out from the N. point of Havaru-Tinadu into the channel between, towards a similar point from Mahuta. The W. end of Mahuta is of rock, and a series of coral pinnacles on the sand-flat behind the boulder zone attests the former connection of the islands across their dividing channel in this position.

The lagoon-flat to the S.E. of Havaru-Tinadu is remarkable for the weediness just behind its edge, which is clothed with corals of massive facies; it slopes gradually to the lagoon. Across the two passages to the S. the waves were breaking, making any examination impossible.

[1] One of Moresby's marks—probably of his original triangulation of the atoll—still exists behind this point. It is 120 yards from the lagoon shore at the S. of the bay, and consists of a square metal bar let into the ground, the end at the present time projecting for about 2½ feet.

Our impression was that they were closing up by lateral as well as bottom growth, while the lagoon in the immediate vicinity is deepening, our anchorage, where 17 fathoms were marked, being 20 *f.* The former presence of a velu opposite Mahuta, now opening into the lagoon, is interesting.

None of the lagoon islands in this vicinity nor to the W. are inhabited, and all are stated by the natives to be washing away. **Gula** and **Hibadu** to the N. have much dead and fallen timber. An unnamed island, marked in lat. 0° 37′ N., has completely disappeared, save for a few rocks on the centre of its shoal, covered at high tide. Such reefs as there are within the lagoon extend generally in the direction of the currents, and mostly have precipitous slopes. No marked growth in any was noticed except near the large W. passage in lat. 0° 45′ N. On the contrary Hibadu and Gula had practically no reefs opposite those shores where fallen timber lay, showing that loss of land and reef was taking place almost simultaneously. The large shoal opposite a passage in lat. 0° 41′ N. appeared also to have broken up into five smaller reef patches.

XI. Addu Atoll (Fig. 109).

The most important changes in this atoll have already been dealt with in Appendix A,

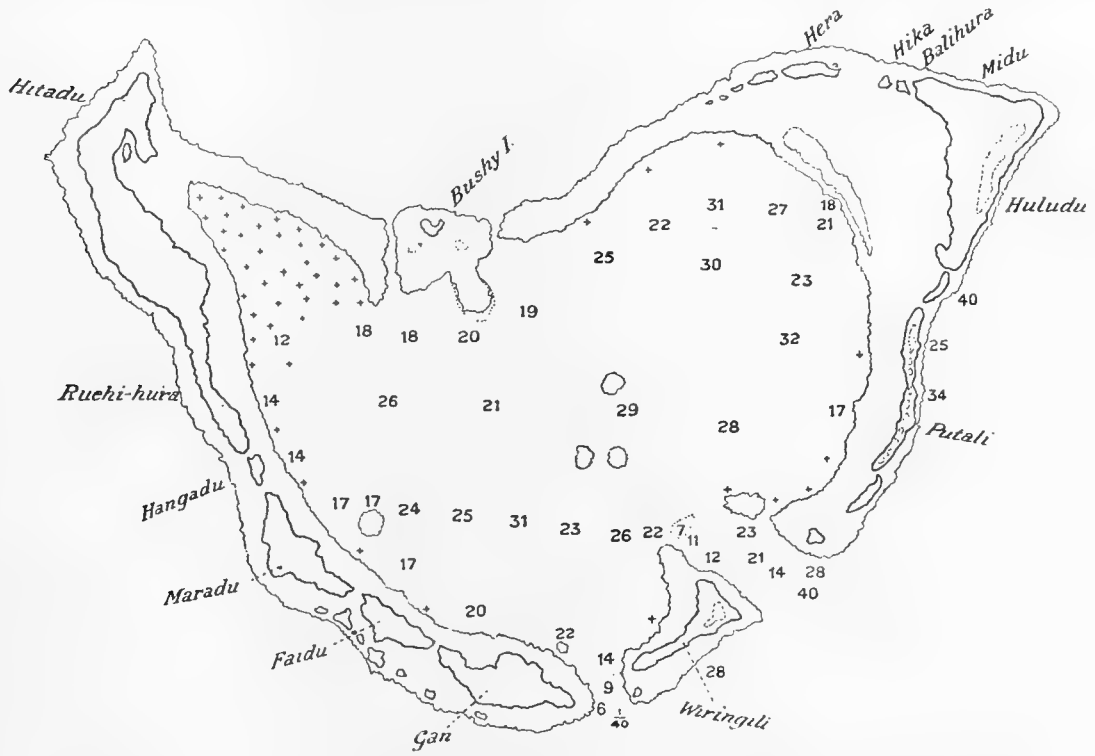


Fig. 109. Addu Atoll. The map is based on the Admiralty Chart, altered in accordance with the observations of the Expedition. Mr Forster Cooper's soundings alone are marked. Scale 2 miles to 1 inch. (*For changes compare the Admiralty Chart on* p. 150.)

Section II. "The Formation of Lagoons." The land shows differences at either end of every island, so that the atoll being small, we could get no even approximately fixed points for our

sights, and the positions of fresh land must only be taken in our chart as comparatively correct.

With regard to the islands themselves they do not differ in structure from those in any other part of the group. All lie on the rim reefs, and the rule is that whatever part of each island falls within about 250 yards, or a little less, of the reef edge is of raised coral rock, and that the remainder is of sand. The greatest height of the rock was found in Hera, *i.e.* 6 feet above the high-tide limit, or about 10 feet above the reef-flat. Rain water denudation has probably been greater in this atoll than in any other, so that there is possibly but little difference between the elevation here and in the rest of the group. The sandy areas of the islands only attain a general height of about 3 feet above the high-tide limit. The sand itself shows that they largely owe their origin to the elevation of sand-flats behind the original enclosing reefs. The surface of the ground, however, has generally been further raised by blown sand, so that the level of the original flats can only be traced in pools, pits and wells.

The seaward sides of the islands show less washing away than in any other atoll. The reef-flat is generally well characterised and relatively broad, merging into a rough or boulder-strewn zone at the base of the beach. The force of the waves is broken before they reach the latter, so that it commonly presents a much smoother appearance than usual, the coral rocks and masses being bedded in sand. In places the latter has become indurated with carbonate of lime, so that there is a broad line of rock at the base of the beach from the half to the low-tide limit. Pinnacles and large masses of the coral rock are not common on the beach, and the appearance decidedly points to the land being at the present time almost stationary, so far as loss is concerned.

It may be here observed that the elevated coral rock of Addu atoll resembles that found at Minikoi and elsewhere, but has always a greater percentage of sand. The corals in it show a more open texture, a more luxuriant growth, and hence the whole rock, being more brittle and open, wears away more evenly than elsewhere.

The outer reef of the atoll is noticeable for its marked edge, less fissured and more defined than usual, but the whole covered with growing organisms. The slope off it is relatively smooth and very densely crowded with growing coral. From its appearance there can be no doubt that it is growing upwards and outwards. Yet on the east side the steep seemed to commence at about 160 yards from the edge of the reef, hence considerably nearer than off the oceanic sides of some of the other atolls of the Maldives. It was observed, though, that the outer slope to the commencement of the steep broadens at every point, showing growth especially in such positions. So far as change has taken place in the contour of the atoll since Moresby's survey, there is no evidence, but the chief points to seaward are all more emphasised and prominent at the present day than shown in his chart. To the south of Huludu there is a shallow bay rather than a point, and Midu point seems very distinctly to have grown out to seaward. The growth also of Wiringili reef to the south and east is seen in distinct points.

Hera, etc. The chart in this position shows six small islands immediately off the N.W. point of Midu, whereas we found two small islets close to the point, separated by a gap about 400 yards broad from a clump of five islets further to the W., of which Hera is the largest. These five form a line on the inner part of the reef-flat or boulder zone, which is clearly

marked between Hera and Hika, and again for some distance along the reef to the W. of the former island.

All these islets are formed entirely of coral rock with the exception of Hera, which, in its broadest part, 130 yards, has on its inner side an accumulation of sand washed up from the lagoon. The small island to the N.E. of Hera is covered with coral stones and may be of quite recent formation. The boulder zone is partially formed of masses of rock, torn off the reef outside or washed off the shores of the islands, but is mainly part of an originally continuous land connection of all these islands to Midu.

Off Hika the shore to the N. presents a steep beach, falling 6 feet, the first 4 feet almost a cliff. This is succeeded by a rough slope, 30 yards broad, passing gradually into a reef-flat of the same breadth. There is again an area of about 20 yards outside the last, with a slight slope to the edge of the reef, which is in this position almost devoid of fissures.

Midu and **Huludu.** Approaching the N.E. corner of the atoll, the reef-flat becomes noticeably bare and smooth, and even broadens further up to 120 yards. Nullipores become dominant towards the point, and cover the whole surface at the edge, which is deeply fissured. The beach passes directly into the reef-flat, there being no boulder, or rough, zone. It is formed of loose rocks, bedded in sand, and may in any place have a small formation of beach sandstone.

Round the seaward side of the whole island, except at the extreme S. end, the rock forms a narrow line, its greatest height about 5 feet above the high-water mark. Towards the interior of the atoll the rock merges to the N. and S. of the island into the sandy area, and is to some extent covered by it. In the centre, however, there is a great rush-covered kuli or lake of fresh water, varying up to 250 yards in breadth. This is cut off by the rock from the sea and by a great sand-flat 3—4 feet high from the lagoon, through which it has retained an overflow channel opening into the lagoon in the centre of the W. side of the island. The sand of the bottom of the kuli and below the tidal limits is everywhere largely foraminiferal and of coarse texture, while that of the surface of the land is fine and mainly formed of ground-up coral. The sandy area of the island, therefore, probably owes its origin to the wind having piled up a bank which effectively cut off the lake from the lagoon.

A small horn to the south of Huludu, stretching northwards into the lagoon, is of interest. It has been partially washed up from the channel to the south of the island, and partially formed by the blown-up sand from off the lagoon-flat. It is evidently growing northwards, and appears likely in course of time to cut off another kuli from the sand-flat.

The islands south of Huludu to the S.E. passage number four, but differ from the chart in the second, Putali being by far the largest. All show a line of rock against a broad reef-flat with sandy areas behind. The seaward beach resembles that off the lighthouse of Minikoi, and further the reef in general appearance is the same.

The northernmost island has a small sand cliff with a few fallen bushes against the lagoon, and Putali at its most southerly seaward point has also some fallen shrubs, but elsewhere none of the islands showed any distinct change in progress. From the appearance of the channels though, to the N. and S. of Putali, it seems to me to be probable that the islands are coming together to form one continuous whole. To the S. of this island there are signs of two points growing out, one by the sea and another against the lagoon. Should these fuse with the next island to the S. a kuli would be formed, quite similar to any one of a series of about twelve rounded pools found in the centre of Putali itself. There is nothing, however, in the structure of the land by these kuli to suggest that any one of them has been formed in this way rather than

by a piling-up of sand, such as has formed the kuli of Midu-Huludu. Further their serial nature along the centre of a very narrow island is scarcely consistent with the second view. Lastly, in the centre of Putali the sea has broken its way through the outer line of rock into two of the pools; the damage, however, had been repaired by the natives with large stones.

Wiringili. The two islands marked on the chart have become joined by a sand-bank, the trees on which are still small. The island is stated by the natives to have a small kuli behind its E. point. The seaward reef is much strewn with boulders, which have accumulated in a bank with three green shrubs at the S. end. The seaward points of the reef are notably shallow for some distance beyond the reef edge.

Bushy islet to the north of the atoll now consists of a single island covered with shrubs and two sand-banks.

The east islands show five in the series instead of four as represented. This is due to the presence of a small island between Maradu and Ruehi-hura, which was probably accidentally joined to the latter in the original survey. The islands are all formed of sand on their lagoon side, which in some places shows an extension, and in others a washing-away. All are slightly lower in the centre but without definite kuli, although mangroves grow in some. All have more or less stony seaward beaches, but the presence of a rocky area depends on the distance of their shores from the reef edge. Off **Hangadu** the reef is about 150 yards broad, and the island has a narrow, rocky line. N. of this the reef narrows, becoming first quite similar to the reef off Hera; and then off **Hitadu** the land extending to the inner edge of the boulder zone. The reef-flat off these parts has no pinnacles or other rocks, being quite smooth; the rocky area in the land is always well-defined. The timber, with which the latter is clothed, rises for some distance back from the beach, suggesting that it is growing outwards by additions from its reefs. At the W. point of Hitadu this is undoubtedly the case, as also along the N. side, but it is less marked to the S. A characteristic feature of Addu, most noticeable here, is the large amount of sand found with the rocks on the beach in places, the whole appearing to be mainly formed by it. On this side of Hitadu, however, we saw no trace of a beach sandstone formation. Off the reef edge the slope is extremely gentle, the sea breaking in a gale over 100 yards outside the reef edge off the W. point of the atoll.

Maradu is separated from Hangadu by a pool of water 2 fathoms deep, although both to the E. and W. their reefs are continuous. This pool is evidently filling up, consequent, I think, on the reef against the lagoon having reached the low-tide level. There are traces here of a former passage into the atoll-lagoon in a less consolidation of both the seaward and lagoon edges of the reef, the latter being still very imperfect and the former having practically no boulder zone. The island of Maradu itself shows growth along its reefs, as do Faidu and Gan. This should ultimately join all these islands together, but the growth may only be temporary. Further N. by Ruehi-hura there were signs of an irruption of the sea across the land, but no definite gap was created.

The reef off Maradu has a high crest, nullipore-covered edge, but relatively small fissures. The reef-flat is about 40 yards broad, and behind this there is a boulder zone about half as broad, with a boat channel, having everywhere at least a breadth of 90 yards to the land. The boulder zone is low, covered by small loose rocks, and is simply the inner part of the reef-flat. It has here no connection with any elevation of the atoll. Further in, the island of Maradu is all of sand formation, a little beach rock indicating a former washing-away of its eastern shores, which now seem almost stationary.

Faidu and **Gan** resemble Maradu, but Gan runs out into a great flat, half-a-mile broad, across which lines of rock extend out to the boulder zone. The latter is in this part of the

atoll very much diffused over the flat, which nowhere at low tide has more than a foot of water. The extraordinary point about this reef is the presence of seven small uncharted islands between Faidu and Gan and the seaward edge of the reef. The first of these is a small stony islet just inside the boulder zone opposite the centre of Gan. Then there is a sand-bank in the corresponding position off the W. end of Gan. On the seaward side of the E. end of Faidu there is a good deal of fallen timber, showing washing away, and between the island and the boulder zone are no less than 15 masses of rock on the reef. Off the centre of Faidu, and opposite the passage between Faidu and Maradu, was a large coconut-covered island, with outside it three smaller islets covered with low bushes, an additional stone bank with a few shrubs lying to the N.

It is important to consider the formation of these additional islands, all of which at some point touch the boulder zone. Unfortunately I was unable to visit them, but they certainly seemed to have been formed of loose boulders and sand, piled up by the waves. I cannot by the study of the chart bring myself to believe or imagine that these islands may have been formed by the washing away of the land behind them, nor that they can have existed when the chart was made. I think it is more than probable that the land behind them has washed away somewhat since 1835, but of any considerable action there are no traces, such as would be bound to be left on the reef if these islets had been formed in this way. It is most remarkable that this fresh formation of land should have occurred on this area alone in the atoll, the action being evidently purely local and isolated. Considering the whole formation, I am driven to the perhaps rather lame conclusion that the physical conditions in the S.W. of the atoll differ from those in other parts sufficiently to have in the first place produced a broad reef-flat, largely by the washing away of the land, which loss is now being repaired by the formation of a fresh series of islands along the boulder zone of the reef. This of course suggests a possible fresh origin for kuli, but those of the E. rim were certainly not formed in this manner.

XII. Other Atolls.

I only caught a fleeting glance of the south-east rim reefs of Ari atoll, but from native accounts I have no doubt but that the bank closely resembles the two Nilandu atolls. We anchored for one night to the south of Mahiaddu (lat. 3° 46′ N.) in the entrance to the broad passage of which we found two shoal patches growing up, with respectively 3 and 5 fathoms.

Wattaru atoll differs in no respect from the chart, save that there are now islands with coconut-trees on either side both east and west of its single channel to the south. According to native accounts Fua-Mulaku has a pool or kuli of fresh water in the centre with strange fish, and the lagoon of Makunadu is said to be both considerably larger and deeper than appears in its chart. Toddu, Karidu, Alifuri, Tiladumati, and Ihavandifolu were not visited either by my companion or myself. They are extremely unlikely, however, to present any points of interest, except perhaps in their outer slopes, that have not already been considered in other atolls.

APPENDIX C.

Concluding Remarks and Notes.

In concluding my account of the Coral Reefs of the Maldives, the investigation of which was the main object of my expedition to that Archipelago, it is fitting that I should state and acknowledge the personal help and assistance I have received.

In the first place I would express my great indebtedness to all my teachers and colleagues in the Zoological Laboratory at Cambridge. It would be invidious were I to mention any name besides that of Mr Adam Sedgwick, to whose constant sympathy is mainly due any merit that my investigations may have. In particular I am obliged to him for reading over Chapters v.—vii. of this Paper and for much most valuable and suggestive criticism.

To the expert knowledge of Adm. Sir W. Wharton, Chief Hydrographer, Sir John Murray, and Mr J. Y. Buchanan I owe much. The first gave me most valuable advice as to navigation, seasons, etc. from which I drew up my itinerary, besides lending me many valuable instruments. I have had on three occasions the advantage of "thrashing out" the question of Coral Reef Formation with Sir John Murray. I am pleased that my investigations in the main support his theory, a result which I did not consider probable when I left home for the Maldives.

Prof. Hickson, Prof. Judd, Prof. Herdman, Mr W. T. Blanford and other experts have given me valuable help in considering various points. They will find replies to some of their criticisms in Appendix A. With my companions on the Expedition, Mr L. A. Borradaile and Mr Forster Cooper, I have discussed most points that have arisen, and the former has read through my manuscript. To those gentlemen, who are so kindly working out my collections, I would express my sincerest gratitude; the results of the Expedition would be of little value without their aid.

I account it a great good-fortune that I have been followed both in Fiji and in the Maldives by Prof. Alex. Agassiz, the greatest and most experienced authority on all questions connected with Coral Reefs. I am greatly obliged to him for allowing me to discuss their formation with him on several occasions previous to his visit to the Maldives. My work dealing mainly with the surface waters (down to 50 fathoms) will, I trust, form a complement to his deeper-water investigations. I have tried to give all the facts without prejudice, but no doubt at least some of my views may have to be modified. In particular the occurrence of manganese nodules in the deeper waters of the Maldives is a fact of no small interest as bearing on the probable character of the foundation rock on which the group has been built.

No doubt Prof. Agassiz's full account will shortly be published, but I may be permitted to quote the summary of his soundings between the banks[1]. "Our soundings showed a greatest depth of 251 fathoms in the center of Gallandu Channel, which separates Ihavandiffulu from Tiladumonati; 769 fathoms in the center of the channel between Miladummadulu and Fadiffolu." "We found 302 fathoms between Goidu (Horsburgh atoll) and South

[1] *Amer. Jour. Sci.* ser. 4, vol. 13, pp. 300–1 (1902).

Malosmadulu. In the center of Kardiva Channel on the two sides of Kardiva island we obtained 312 and 298 fathoms with 372 fathoms one-and-a-half miles south of Fadiffolu atoll. One hundred fathoms was obtained in the center of the channel between Gafaru and North Male. Between North and South Male in the center of Wadu Channel we got a depth of 260 fathoms[1]. In the center of Fulidu Channel separating South Male and Felidu atoll we found 374 fathoms. In the channel north of Wattaru Reef we found 283 fathoms; in Wattaru Channel between Wattaru reefs and Mulaku atoll 253 fathoms, and between Mulaku and Kolumadulu the depth in the center of the channel increased to 648 fathoms. Returning now to the groups of the western chain of atolls we found 231 fathoms in the Ariyaddu Channel between Ari and North Nilandu. The charts indicate 200 fathoms in the center of the channel between North and South Nilandu, and between it and Kolumadulu, the northernmost of the southern single chain of atolls, we found 251 fathoms in the center of the channel.

"In the wider channels separating the atolls of the southern single chain the depths become much greater. In the center of the Veimandu Channel, which separates Kolumadulu and Haddumati, the depth had increased to 1118 fathoms, and halfway between it (Haddumati) and Suvadiva we found a depth of 1130 fathoms. In the wide channel between Suvadiva and Addu we found 1292 fathoms a little to the north of Fua Mulaku, and 1048 fathoms between it and Addu. At a distance of four-and-a-half miles to the south of Addu we ran into 718 fathoms."

In the body of this Paper, particularly in Chapter VI. on North Mahlosmadulu, I have laid great stress on the changes shown by the islands, reefs and faro since the original survey of Capt. Moresby in 1834–6. Any single change might well be due to an error, but *the vast majority* of these small differences point in the same direction. I accordingly maintain that these diversities show real changes and indicate the actual development now going on in the Maldive Group. Even without the comparison with the original charts the facts, if correctly stated above, as to the changes now in progress are sufficient to prove most of the changes, which the comparison perhaps more clearly brings out. Even for Addu Atoll, which so markedly differs from the rest of the banks, I cannot but suppose that the alterations found are real ones. Adm. Sir W. L. Wharton, however, when I lectured before the Royal Geographical Society, sounded a note of caution[2], which his high authority impels me to quote at length. "There is one point I think I ought to mention. I do not quite think that Mr Gardiner can rely so implicitly as he does upon the exact accuracy of the shape of these little atollons (faro) in the Maldives as they were mapped by Capt. Moresby. If you come to think of it, this long line of islands extends for nearly 500 miles in a double line and over considerable width, and was mapped during three seasons in a small sailing vessel, and it is quite impossible—I know what the system of surveying of that day was—is quite impossible that the reefs could have been more than very, very roughly sketched." "In a great many cases it is noted down in the original surveys 'depth given by the natives,' 'depth reported,' and so on. This has (sometimes) been left out in the published chart to simplify matters."

Of other questions not already dealt with in the body of this paper a reference may be made to the food of the reef-building corals, on which a number of observations were

[1] I take this opportunity of correcting an error on p. 11, line 2 of the "Introduction" to this Publication in respect to the single *deep* sounding we made; for "S.W. ¼ W." read "S.E. ¼ E."

[2] *Geogr. Jour.*, vol. XIX. no. 3, p. 297 (1902).

carried out. These served fully to confirm my previous work on the subject, but most reef-corals evidently ingested a certain amount of organic food, although the vast majority undoubtedly obtained their nutriment principally through the agency of their commensal algae. The polyps of such genera as *Euphyllia* and *Prionastraea*, in which no definite gastrovascular cavity seems to be present, seized fragments of weed and animal matter when placed by me within their reach. The presence of dead organic matter in about 1 or 2 per cent. of the preserved polyps of *Pocillopora* and *Astraea* points to the same method of feeding sometimes occurring in nature, although there seems no doubt but that these same corals feed mainly by means of their commensal algae.

The occasional death of all the species of corals over considerable areas of the reefs by silting up after heavy gales and cyclones is well-known, and was observed by us in several places. I would emphasize the fact that in such cases practically all the coral colonies of all the genera found in the area are killed. In addition separate coral colonies may be here and there found killed by such a cause, probably by some purely local change. Usually the absence of corals, etc. on reef-flats, in other respects suitable for their growth, seems to be due to the waves and currents in such places moving fine material from the reefs and shores. A series of experiments on transplanting corals to barren areas was entirely unsuccessful so far as the growth of the animals was concerned, the colonies, when not washed away, being *in every single place* killed by silt.

A number of experiments were carried out on the exposure of colonies of several genera of reef-corals to the air and sun. The living masses of various genera differed enormously, but all, so long as they had some part of their polyp layers kept constantly moist by (*i.e.* immersed in) the water, appeared to be able to live for at least 5 hours, even when exposed to the full force of the sun. The colonies of most genera when placed on the beach for the whole night or for 1—2 hours in the full force of a tropical sun were quite capable of expanding again when returned to the water. These experiments point to the fact that the ordinary exposure—or even the extraordinary exposure after heavy winds—of corals on the reef at low tide to the air and sun does not kill or otherwise destroy such coral colonies as may stand up out of the water.

Yet the death of coral colonies on reefs is of common occurrence, and has been mentioned by most authors. In the Pacific, as well as subsequently in the Maldives, I frequently observed separate, dead coral colonies, as well as the death of all the colonies of *individual species* of corals over relatively wide areas. In the majority of these cases the separate corallites did not appear to have been in any way silted up, nor were many of the colonies in such positions that they could by any possibility have been killed by exposure either to air or sun. Separate dead colonies also were often found where neighbouring colonies of the same and other species of all sizes were flourishing. They were generally of considerable size, and in the absence of any visible environmental cause, I am inclined to assign their death to senile decay, a phenomenon I have found well-marked in *Flabellum* and other corals.

An entirely different case is where the dead skeletons only of a single species of coral were found on one reef, while on the next the colonies of the same species were perchance growing luxuriantly. At the time I did not appreciate the importance of this phenomenon, but I recorded in my notes a large number of instances of the absence from particular areas of living colonies of individual common species of corals, while the dead coralla of the same species were common. I have already given a few instances and, to some degree, discussed

the subject in a paper entitled, "Some Notes on Variation and Protandry in *Flabellum rubrum* and Senescence in the same and other Corals[1]," but I draw further attention to it here, in the hope that future visitors to coral-reef regions will pay attention to the subject. "If—as I am impelled to believe—the ripening of the generative organs of a large number of polyp colonies of the same species in a single locality or habitat, followed by the subsequent death of all these colonies, is a regular phenomenon, the consequences must be of the most wide-reaching importance in the formation of coral reefs." "Remembering the occurrence of a ciliated larva in the Madreporaria, it is impossible to believe that the colonies of a single species in any area are of the same age—they certainly are not of the same size, and hence have not a like number of polyps. It is consequently necessary to suppose that in an area—owing probably to some change in the physical conditions of their environment—all the corals of some single species have been stimulated to ripen and dehisce their generative products at the same time, the act leading ultimately to their weakening and death." The only analogous case that I know of in nature is that of the bamboo, every plant of which in a district produces its fructification at the same time and dies[2]. The analogy is not complete, however, for whereas the individual polyps of a colony go on producing ova or spermatozoa during the whole of their life, the bamboo merely sets one enormous fructification, which apparently uses up all its energy and causes its death.

At the last meeting of the British Association, and in the last Part of this Publication[3], I discussed to some extent the importance of algae as agents in the disintegration of corals. As I go to press I have to thank Mr J. E. Duerden for an important paper on this subject, which he has been kind enough to send me. Mr Duerden's conclusions, derived mainly from the examination of W. Indian corals, are strikingly in accordance with mine, and go much further with regard to this one class of organisms. Mr Duerden[4] found in 30 W. Indian corals that he examined the tubes of algae of the genera *Gomontia* and *Ostreobium* penetrating every part of the different coralla, but their living filaments were only present in the more superficial parts of the different colonies, to which alone light could penetrate. Twelve fragments of coral, obtained by Prof. Agassiz in the Pacific in 1899—1900, when decalcified revealed in every case the presence of filamentous algae. "The results presented above give good reason for assuming that in general all corals are infected with boring algae, even to their most superficial regions of growth." "Once a coral is attacked by these (algae), the growth of the ramifying filaments apparently never ceases so long as the necessary conditions of plant life remain; even when the dead coral is broken up into fragments the growing filaments still continue their corroding action on the separate particles, and by the production of soluble bicarbonates lead to their ultimate disappearance."

[NOTE. For an account of the biology and species of the reef-building plants see "The Lithothamnia of the Maldives and Laccadives," by M. Foslie in the same Part of this Publication.]

[1] *Proc. Camb. Phil. Soc.* vol. XI. pp. 463—71 (1902).

[2] Mr W. T. Blanford in a letter remarks that he has "seen more than one instance of a particular species of bamboo having perished over hundreds of square miles of country." He further points out that the bamboos are wild plants, whereas in the paper already referred to I unintentionally inferred that the phenomenon was found only in cultivated ones.

[3] *Vide* p. 325, and also p. 116 in Part 2.

[4] "Boring Algae as Agents in the Disintegration of Corals," *Bull. Amer. Mus. Nat. Hist.* vol. XVI. pp. 323—332 (Sept. 25, 1902).

MARINE CRUSTACEANS.

PARTS IV.—VII.

By L. A. Borradaile, M.A., *Lecturer in Natural Sciences at Selwyn College, Cambridge.*

(With Plate XXII. and Text-figures 110—119.)

IV. SOME REMARKS ON THE CLASSIFICATION OF THE CRABS.

When Boas, in 1880[1], reorganised the classification of the Decapoda, abolishing the distinction established by Fabricius between the *Macrura* and *Brachyura*, and dividing the order anew into *Natantia* (Prawns and Shrimps) and *Reptantia* (Lobsters and Crabs), he left the crabs (*Brachyura*) untouched, as a single tribe of the Reptantia. Within this tribe he recognised two subtribes, one comprising the primitive *Dromia*-like forms, in which the orbits, the abdominal limbs, the gills and other features recall the Macrurous tribes, and the other containing all the rest of the true crabs. These subtribes he called respectively *Dromiacea* and *Brachyura genuina*. Ortmann, however, elaborating Boas' scheme in 1896[2], took the step of dividing the Brachyura into three groups, each of which he made equal in rank to the other subdivisions of the Reptantia (*Astacidea*, *Loricata*, etc.). These groups were: (1) Boas' Dromiacea, under the name of *Dromiidea*, (2) the old division *Oxystomata* established by Milne-Edwards for the crabs like *Calappa* and *Leucosia* which are modified for life in sand, and (3) the *Brachyura*, comprising the remainder of the crabs. In the *Brachyura* he recognised, with some alterations, Milne-Edwards' divisions *Oxyrhyncha* (Spider Crabs), *Cyclometopa*[3] (Round-fronted Crabs, including *Cancer*-like genera), and *Catometopa* (Square Crabs).

It may be admitted that Ortmann was well-advised in establishing his three main groups of Crabs. If he be right—as, in the opinion of the writer of this paper, he is right—in regarding the Oxystomata as derived from the Dromiacea independently of the Brachyura genuina, then it is clearly misleading to retain Boas' arrangement, in which the Dromiacea

[1] Boas, J. V., *Kong. Danske Vidensk. Selsk. Skriften* (6), I. p. 23.

[2] Ortmann, A. E., *Zool. Jahrb. Syst.* IX. p. 409.

[3] Ortmann at first applied the name *Cancroidea* to this group, his *Cyclometopa* forming only a part of Milne-Edwards' group of the same name. Later (Bronn's *Thierreich*, Crust. II. p. 1165) he returned to the use of the term Cyclometopa as including all its former genera, making it thus synonymous with Cancroidea.

are opposed to a group containing the Oxystomes together with the rest of the crabs. But quite apart from this consideration is the fact that the Oxystomata have certain well-defined features which give them a unity such that it would in any case be necessary to oppose them to the rest of the Genuina; and, if this be not done by raising them to the rank of the Dromiacea, then a new grade of classification must be introduced within the Genuina, which must be separated into Oxystomes and non-Oxystomes. Such a step would be most undesirable in view of the already complicated system of the Decapoda.

At the same time I am unable to follow Ortmann in raising the three groups of crabs to the same rank as the Astacidea or Paguridea. The crabs are a true group with a common phylogenetic origin from Macrurous forms of the Reptantia through the Dromiacea. Moreover, besides the shape of the body, there are three features which are almost absolutely diagnostic of the Brachyura in the old sense of the word: (1) the loss of the last pair of abdominal limbs, (2) the fusion of the shield of the cephalothorax with the epistome in such a way as to form two sockets for the sense organs of the two sides, and (3) the broad, unjointed endopodite of the first maxilliped, with its marked outer angle (Fig. 110). In these circumstances I follow Boas in keeping all the crabs together as a single tribe, *Brachyura*, of the Reptantia. If we thus use the word in its old, full sense, it becomes needful to find another name for Ortmann's Brachyura (= Boas' Brachyura genuina without the Oxystomata). For this group I have already proposed[1] to use de Haan's name *Brachygnatha*.

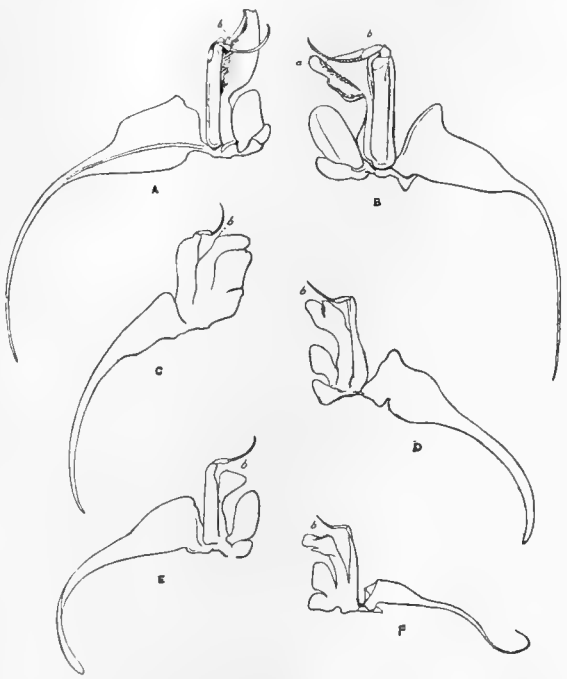


FIG. 110. The first maxillipeds. A. *Calappa*, B. *Portunus*, C. *Dromia*, D. *Cardiosoma*, E. *Cancer*, F. *Uca* (= *Gelasimus*), *a*. the inner lobe characteristic of the Portunidae, *b*. the outer angle, well-marked in crabs.

I now pass to the consideration of the subdivisions of the Brachygnatha. The Oxyrhyncha form a natural and, on the whole, well-defined group, but a boundary between the Cyclometopa and the Catometopa is absolutely wanting. This is especially the case between the Gonoplacidae and the Xanthidae, where the transition is made complete by such genera as *Pilumnoplax* and *Platypilumnus*. The Potamonidae also are far from presenting an easy problem in their affinities. And the genus *Catoptrus*, while it seems clearly allied with the Carcinoplacinae, is extraordinarily like the Portunidae, this likeness extending even to the form of the first maxilliped, which is peculiar to the latter family (B. Fig. 110). In view of these facts I propose to unite the Cyclometopa and Catometopa into a single group, for which I propose the alternative titles *Brachyrhyncha* and *Cancroidea*[2], corresponding

[1] *Proc. Zool. Soc.* 1900, p. 568. This term in its original meaning included the Dromiacea as well as the Cancroid forms, but it has so long been in disuse that its revival in a somewhat altered sense would cause no inconvenience.

[2] This word was used by de Haan (in von Siebold's "Fauna Japonica") with practically the same meaning as that given to it here.

to those applied to the spider crabs, *Oxyrhyncha* and *Maioidea*. The group thus formed presents a series of families, long and varied indeed, but neither more numerous nor more diverse than, for instance, those included in the Caridea (Eukyphotes).

With regard to the position of the remarkable family Hymenosomidae I am in agreement with Ortmann in provisionally placing them among the Oxyrhyncha. The genus *Catoptrus* A. M.-Edw., 1870 (= *Goniocaphyra* de Man, 1887), which I have already[1] proposed to make the type of a subfamily of the Portunidae, I shall for the present continue to keep in that position, in spite of the fact that, if *Catoptrus* seems clearly related to *Carupa* and perhaps also to *Caphyra* among the swimming crabs, it has hardly less clear resemblances to *Libystes* and *Carcinoplax* among the Gonoplacidae. The Hapalocarcinidae should, I believe, be placed somewhere among the Brachyrhyncha but, in view of their exceedingly doubtful affinities, are not included in the key given below. For the same reason the family Trichiidae, which should probably be established for *Trichia* de Haan is also left unmentioned. Lastly, I have followed Alcock in placing *Palicus* near the Catometope families. The accompanying table gives the classification of the Brachyura, as it will stand with the changes proposed above, and the characters on which it depends are summarised by means of a series of keys.

Subtribes of the Brachyura.

I. Fore edge of the mouth-field (endostome) prolonged forwards to form a gutter. [Last pair of legs normal or abnormal. Female opening generally sternal. First abdominal limb of female wanting. Gills few.] *Oxystomata*[2].

II. Mouth-field roughly square.

A. Last pair of legs abnormal, dorsal. Female genital opening coxal. First abdominal limb of female present. Gills usually many. *Dromiacea*[2].

B. Last pair of legs normal, rarely reduced, not dorsal, except in *Palicus* and *Ptenoplax*. Female genital opening sternal. First abdominal limb of female wanting. Gills few. *Brachygnatha*.

Legions of the Brachygnatha.

I. Fore part of body narrow, usually forming a distinct rostrum. Body more or less triangular. Orbits generally incomplete. *Oxyrhyncha*[2].

II. Fore part of body broad. Rostrum usually reduced or wanting. Body oval, round or square. Orbits nearly always well enclosed. *Brachyrhyncha*.

Families of the Brachyrhyncha.

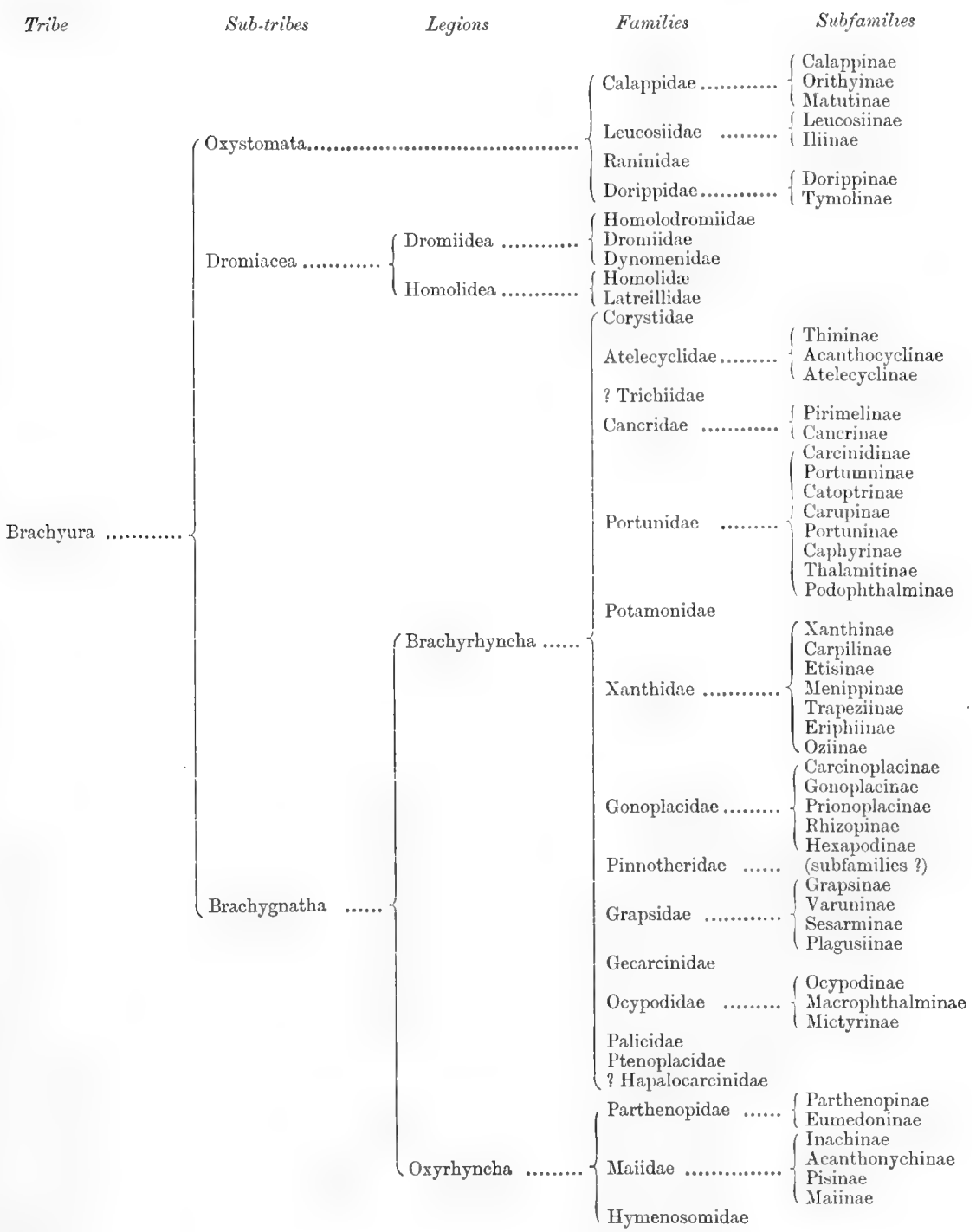
I. Orbits formed but more or less incomplete. [Antennal flagella, when present, long and hairy. Rostrum present. Body elongate-oval. Fore edge of the mouth indistinct.] *Corystidae*.

II. Orbits complete (though fissures may remain), except in the Mictyrinae, where the eyes are almost or quite unprotected. [Body rarely elongate-oval. Rostrum often wanting. Antennal flagella usually short, not hairy.]

[1] *Proc. Zool. Soc.* 1900, pp. 578, 799.

[2] For key see the article on the group.

TABLE SHOWING THE DIVISIONS OF THE BRACHYURA.



A. Carpopodite of 3rd maxilliped articulates at or near the antero-internal angle of the meropodite. [Body usually round or transversely oval. Male opening nearly always coxal.]

1. Legs more or less distinctly adapted for swimming. [Antennules fold slanting or transverse. Usually a small lobe on the inner angle of the endopodite of the 1st maxilliped[1].] *Portunidae.*

2. Legs not adapted for swimming. Or, if so modified, then the vas deferens opens sternally or runs in a sternal groove (certain *Macrophthalmus* and *Libystes*). Inner lobe on the endopodite of the first maxilliped wanting[2].

a. Freshwater crabs with the branchial region much developed and swollen. [Body often squarish, but male opening coxal.] *Potamonidae.*

b. Marine crabs, with the branchial region not greatly swollen.

i. Antennules fold lengthwise.

α. Carapace subcircular. Antennal flagella either long and hairy or wanting. *Atelecyclidae*[3].

β. Carapace broadly oval or hexagonal. Antennal flagella present, short, not hairy. *Cancridae*[3].

ii. Antennules fold slanting or transversely.

α. Body usually transversely oval. Male openings rarely sternal. Not sharply separated from the following family. *Xanthidae*[4].

β. Body usually square or squarish. Male ducts open on the sternum or, if coxal, pass along a groove in the sternum. Not sharply separated from the foregoing family. *Gonoplacidae.*

B. Carpopodite of 3rd maxilliped does not articulate at or near the inner angle of the meropodite. [Body usually square or squarish. Male opening sternal, except in *Ptenoplax*, where the duct passes along a sternal groove to the coxopodite.]

1. Small symbiotic crabs with very small eyes and orbits. Body usually more or less rounded. *Pinnotheridae.*

2. Free-living crabs with eyes not specially reduced and usually a square body.

a. Last pair of legs dorsally placed and weaker than the others. [Interantennular septum very thin. No distinct epistome. Exopodite of 3rd maxilliped not hidden.]

i. Front narrow. Female opening in normal position, 3rd maxillipeds subpediform, not covering the mouth. *Ptenoplacidae.*

ii. Front moderately broad. Female openings on the sternal segment corresponding to 1st pair of walking legs. 3rd maxillipeds cover the mouth ventrally and have a very small meropodite. *Palicidae.*

[1] A key to the subfamilies of the Portunidae will be found in the *Proc. Zool. Soc.* 1900, p. 577. The name *Catoptrinae* should be substituted for *Goniocaphyrinae*, Milne-Edwards' name *Catoptrus* having priority of *Goniocaphyra* de Man.

[2] I make this statement on the authority of Ortmann (*Zool. Jahrb.* IX. *loc. cit.*). *Uca* (=*Gelasimus*) and many other genera have a small lobe on the inner side of the endopodite, but this is not at the angle and is a different structure. In *Cardiosoma* the outer angle is divided from the main part of the plate, thus leaving a *large* inner lobe. This again is probably not the same structure as that in the Portunidae (Fig. 110 B).

[3] For key to subfamilies see below.

[4] A key to the subfamilies of the Xanthidae will be found above on p. 238 of Pt. III. in the article on that family.

β. Last pair of legs not dorsally placed nor markedly weaker than the rest. [Inter-antennular septum not very thin except in Macrophthalminae.]

i. A gap of greater or less size is left between the 3rd pair of maxillipeds. Front broad, or moderately so.

α. Sides of the body either straight or very slightly arched. Shape square. Rarely true land-crabs. *Grapsidae*[1].

β. Sides of the body arched. Shape transversely oval. Land crabs. *Gecarcinidae.*

ii. 3rd pair of maxillipeds almost or quite close to the mouth. Front moderately or very narrow. *Ocypodidae.*

Subfamilies of the Atelecyclidae.

I. Antennal flagella absent. [Mouth covered by 3rd maxillipeds. Front uncleft.] *Acanthocyclinae.*

II. Antennal flagella present.

A. Regions not defined. 3rd maxillipeds cover the mouth. Front entire or lobed. *Thiinae.*

B. Regions more or less clearly marked out. 3rd maxillipeds do not cover the mouth. Front toothed. *Atelecyclinae.*

Subfamilies of the Cancridae.

I. Carapace broadly oval. Epistome not sunken. *Cancrinae.*

II. Carapace hexagonal. Epistome sunken. *Pirimelinae.*

V. THE CRABS OF THE CATOMETOPE FAMILIES.

The group Catometopa was as hard to characterise bionomically as it was to separate morphologically from the Cyclometopa. The one thing that could be said about it in this respect was that the bulk of its members lived, not in the sea, but on land, in fresh water or between tidemarks. At the same time a considerable number were strictly marine, especially the Xanthid-like family Gonoplacidae and the Mussel-Crabs of the Pinnotheridae. The land forms have been already enumerated above (Pt. I. p. 64) where some remarks on their habits will be found. Of the others, the only genera to which any striking bionomic interest attaches are *Plagusia* and *Leiolophus*, which live between tidemarks and are very active (see p. 432), *Pinnotheres*, which inhabits bivalve shells, and *Planes*, found on floating objects at sea. *Caecopilumnus* described with the Xanthidae, etc. (p. 267), belongs, I think, to the Gonoplacidae. *Platyozius* described in the same paper is more nearly related to *Pilumnoplax* than to *Pseudozius* but is a Xanthid, as is also *Pilumnoplax*.

All the species which are not new have already been described from the Indo-Pacific region, most of them being Indian. The following list enumerates the species:

[1] A key to the subfamilies and genera of the Grapsidae is given by Kingsley (*Proc. Ac. Philad.* 1880), and the members of most other groups of the old Catometopa can be fairly easily recognised by means of the diagnoses in Major Alcock's paper (*Journ. As. Soc. Bengal*, LXIX. ii. 1900). The points in which the arrangement in this paper differs from Major Alcock's are mostly small and will cause no confusion.

Family **Gonoplacidae.**

Subfamily **Carcinoplacinae.** Genus *Litocheira* Kinahan, 1858.

1. *Litocheira angustifrons* Alc., 1902. Alcock, VI. p. 315[1].

Taken on the reef at Hulule, Male Atoll.

2. *Litocheira integra* (Miers), 1884. Alcock, VI. p. 314.

Taken on the reef at Hulule, Male Atoll. *L. subinteger* (Lanchester), 1900 [= *Carcinoplax integer* de Man, 1887] seems to differ from this species in that: (1) There are three, instead of two, notches on the anterolateral edge. (2) The shape of the anterolateral edge is different, making almost a right angle. (3) The front is narrower.

3. *Litocheira inermis* n. sp. (Fig. 111).

Diagnosis: "A *Litocheira* whose cephalothorax is almost square, smooth, hairless and microscopically pitted; the front arched gently, but with a shallow bay in the middle; the anterolateral edges without teeth but showing traces of two faint notches; the chelipeds short and stout, with one sharp tooth at the inner angle of the wrist and a faint ridge along the lower part of the outside of the hand; and the walking legs stout, with broad end-joints and a beard of hairs on the hinder edge of the last two joints."

Length of the only specimen (a female): 8·5 mm. Breadth: 9·5 mm. Colour in spirit: yellowish-white.

One female was taken at Hulule, Male Atoll.

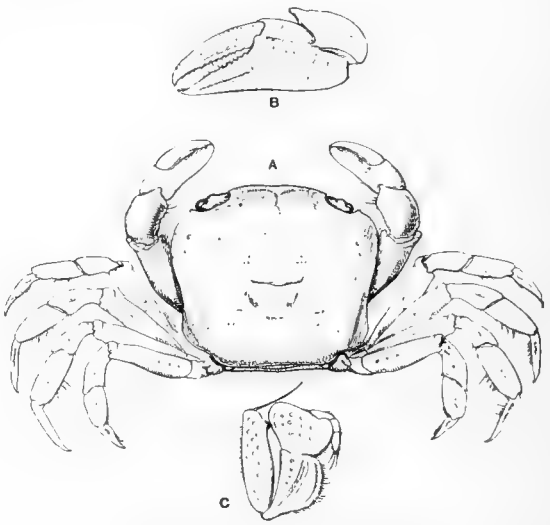


Fig. 111. *Litocheira inermis*; A. whole animal, B. outside of hand, C. third maxilliped.

Subfamily **Rhizopinae.** Genus *Selwynia* n.

Among the crabs collected on the reef at Hulule, Male Atoll, was one which by its diagnostic features should belong to the Rhizopinae, but for which I am unable to find a place in any of the known genera of that subfamily. In proposing a new genus for it I have commemorated my College and its patron saint.

Characters of *Selwynia* n. gen.: (1) *Carapace* broadly oval, without teeth or notches on the anterolateral edge, flat, but falling away in front. Body rather deep. (2) *Front* narrow, bent downwards, bilobed owing to a deep groove in the middle, continued into the interantennular septum. (3) *Eyes* well formed and well pigmented, small, stout, not fixed into the small, close-fitting orbits. (4) *Antennules* fold almost, but not quite, transversely. (5) *Antennae* short, the flagellum standing in the orbital gap. (6) *Third maxillipeds* with meropodite roughly square, a little smaller than the ischiopodite; palp strong, arising nearly

[1] For the principle upon which references are given in this paper see p. 192 of Pt. II. of this publication. Major Alcock's paper on the Indian Catometopes appeared in *Journ. Roy. As. Soc. Bengal*, LXIX. ii. (1900).

in the middle of the fore edge of the meropodite; and exopodite well developed. (7) All the *legs* present and stout. (8) *Abdomen* not nearly covering the last thoracic sternite.

4. *Selwynia laevis* n. sp. (Fig. 112).

Diagnosis: "A *Selwynia* with the body smooth and naked except for some hairs on the underside and on the last three joints of the walking legs, microscopically pitted all over; the regions of the back barely to be made out, the chelipeds very large and stout, their fingers nearly as long as the palm, gaping slightly, finely toothed on their opposed edges, and not furrowed; no thorns or teeth on any of the joints of any leg, save a small tooth underneath the meropodites of the walking legs; and the walking legs very stout, with very small end-joints, the last pair being a good deal smaller than the rest."

Length of the only specimen (a male): 6 mm. Breadth: 8 mm. Colour in spirit: white.

One male specimen was taken at Hulule, Male Atoll.

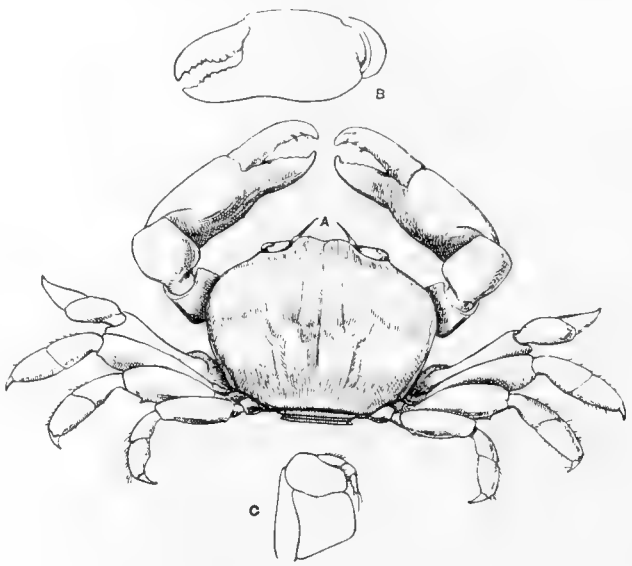


Fig. 112. *Selwynia laevis*; A. whole animal, B. outside of hand, C. third maxilliped.

[Genus *Caecopilumnus* Borradaile, 1902.]

[*Caecopilumnus hirsutus* Borradaile, 1902.] See above, Pt. III. p. 267.

This genus is at least allied to, if not identical with, *Typhlocarcinodes* Alc., 1900. I formerly regarded it as *incertae sedis*, but now believe that its proper place is in this subfamily.

Family **Pinnotheridae.** Genus *Pinnotheres* Latr., 1802.

5. *Pinnotheres purpureus* Alc., 1900. Alcock, VI. p. 339.

Dredged from 30 fathoms, Felidu Atoll.

6. *Pinnotheres tenuipes* n. sp. (Fig. 113).

Diagnosis: "A *Pinnotheres* with the carapace subcircular, smooth, moderately convex; the front rounded and hood-like; the eyes small, well pigmented; the end-joint of the third maxilliped slender, set far back on the inner edge of the joint before it, nearly reaching the tip of that joint; the chelipeds short, moderately stout, with fingers about $\frac{2}{3}$ the length of the palm, and a strong, rounded tooth on the moveable one about $\frac{1}{3}$ of its length from the articulation; the walking legs slender, the second the longest, the second and third nearly equal, and the fourth much the shortest, the last two joints of the walking legs hairy and their end-joints about equal in length, except for those of the fourth pair, which are much longer and more slender than the rest."

Length of the only specimen (a female): 12 cm. Breadth: 13 cm. Colour in spirit: mottled brown.

One female was taken from within the shell of a *Mya* (?) in Minikoi.

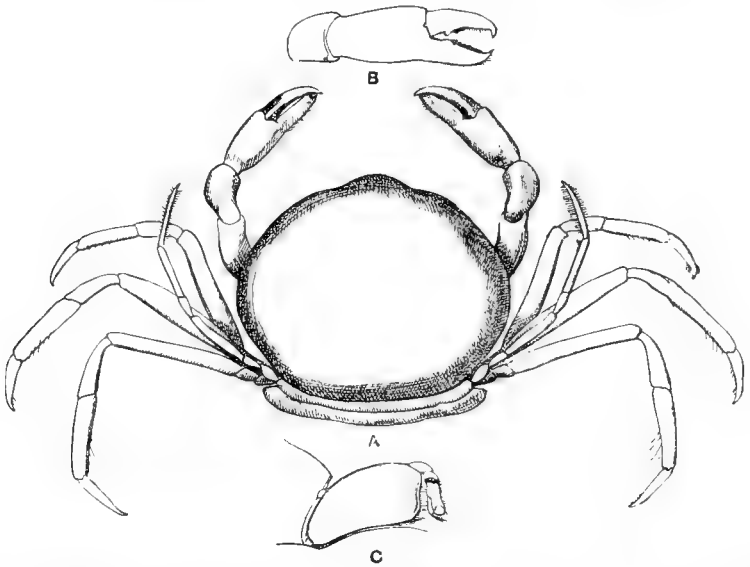


Fig. 113. *Pinnotheres tenuipes*; A. whole animal, B. outside of hand, C. third maxilliped.

Family **Grapsidae.**

Subfamily **Grapsinae.** Genus *Pachygrapsus* Randall, 1839.

7. *Pachygrapsus minutus* (A. M.-Edw.), 1873. Alcock, VI. p. 379.
Taken at Minikoi, and dredged in Fadifolu and Mahlos Atolls down to 25 fathoms.

8. *Pachygrapsus plicatus* (H. M.-Edw.), 1837.
Pachygrapsus plicatus, Kingsley, *Proc. Ac. Philad.* 1880, p. 200.
Taken at Hulule, Male Atoll and Goidu, Goifurfehendu Atoll.

9. *Pachygrapsus planifrons* de Man, 1887.
Pachygrapsus planifrons de Man, *Arch. Naturges.* LIII. i. p. 368, Pl. XVI. Fig. 2 (1887).
Taken in a coral mass on the outer reef at Minikoi.

Subfamily **Varuninae.** Genus *Planes* Leach, 1815.

10. *Planes minutus* (Linn.), 1750.
Nautilograpsus minutus, Kingsley, *Proc. Ac. Philad.*, 1830, p. 202.
Taken at Male on a floating cuttle-bone.

Subfamily **Plagusiinae.** Genus *Plagusia* Latr., 1806.

11. *Plagusia depressa* (Hbst.), 1793, var. *squamosa* (Hbst.), 1790. Alcock, VI. p. 437.
Common all over the Archipelagoes, scrambling actively over the rocks at low tide.

Genus *Leiolophus* Miers, 1876.

12. *Leiolophus planissimus* (Hbst.), 1804. Alcock, VI. p. 439.
Common all over the Archipelagoes. Hides under stones, clinging with its flat body close against them. When the stone is turned, the crab slips away, and is hard to secure.

Family **Ocypodidae.**

Subfamily **Macrophthalminae.** Genus *Macrophthalmus* Latr., 1829.

13. *Macrophthalmus verreauxi* H. M.-Edw., 1848. Alcock, IV. p. 377.

Taken in Felidu Atoll, 30 *f.*

14. *Macrophthalmus latipes* n. sp. (Fig. 114).

Diagnosis, "A *Macrophthalmus* whose length is to its breadth as 5 : 8; with the front very strongly bent downwards; the upper edge of the orbit slightly sinuous, slanting so much backwards that the sharp thorn at its outer angle lies far behind the level of the front; no stridulating organ; the antero-lateral edge with one blunt tooth behind the orbital angle and faint traces of two mounds behind this tooth; eyes outreaching the orbital angle by more than a third of their length; chelipeds small, simple in shape, with one blunt tooth on the moveable finger and no thorn on the inside of the palm; and walking legs with a spine near the end of the upper edge of the meropodites and long slender end-joints, except in the case of the hindermost pair, where the last three joints are broad and flattened."

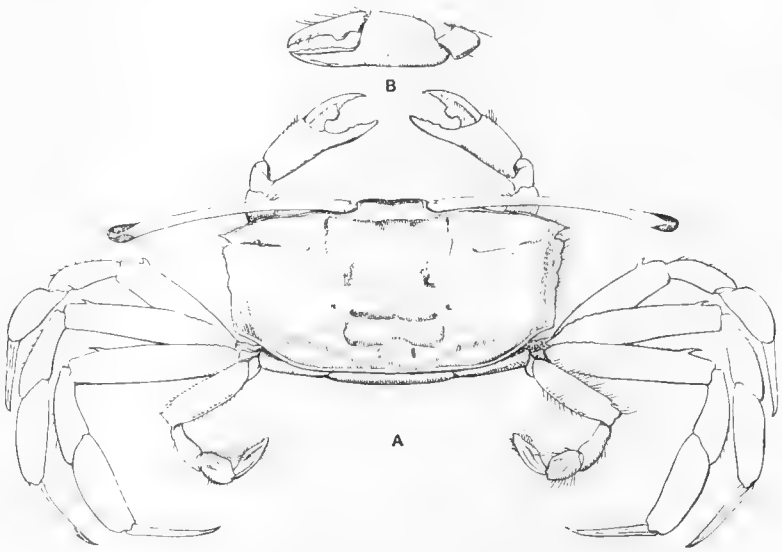


FIG. 114. *Macrophthalmus latipes*; A. whole animal, B. outside of hand.

Length of only specimen (a male): 5 mm. Breadth: 8 mm. Colour in spirit, white. In the flattened shape of its last pair of legs, this species recalls the Portunid genus *Podophthalmus*, already curiously like *Macrophthalmus* in the length of its eyestalks and its broad body.

Dredged from 36 *f.* South Nilandu Atoll.

Family **Palicidae.** Genus *Palicus* Philippi, 1838.

15. *Palicus jukesi* (White), 1847. Alcock, VI. p. 451.

According to Alcock, "the Indian species of *Palicus* live among coral shingle at a depth of from 10 to 40 fathoms, where their mottled coloration and granular rugose carapace afford a good concealment." The majority of the specimens of this species taken by the expedition were dredged on a bottom which contained coral shingle, but several were obtained from foraminiferal mud, quite unlike and unmixed with coral shingle. The species was taken from 25 to 45 fathoms in Suvadiva, Haddumati, South Nilandu, and Kolumadulu Atolls.

VI. THE SAND CRABS (OXYSTOMATA).

The morphological feature by which the Oxystomata are distinguished from other crabs is, at the same time, an indication of their most marked binomic peculiarity. This feature is to be found in the shape of the mouth and foot-jaws. The epistome is small or wanting, and the endostome is lengthened forwards, so that it is of a triangular shape. The channels for the outward stream from the gill-chamber, running on this endostome, are covered in by the long, leaf-like endopodites of the first pair of maxillipeds (*A* Fig. 110), and in this way are prolonged as closed tubes to the front of the body. The whole apparatus is neither more nor less than an adaptation to breathing under the special circumstances that present themselves in the sand-beds which form the characteristic habitat of the group.

The Oxystomata are singularly unanimous in their habits. Nearly all of them are crabs whose strength is to sit still, trusting to concealment rather than to agility or offensive tactics for protection against predaceous animals. Most of them find their concealment in the sand, where they lie buried with only the eyes exposed, and can often only be detected by the little whirlpool which they make in breathing. In such circumstances the advantage of having the breathing channels carried right up to the surface of the sand is obvious, and we have seen how this is done in the case of the outgoing stream. The incoming stream is ordered differently in different families. The Calappidae[1] (Pl. XXII. fig. 6) draw in water, like many other crabs, down a passage formed, so to speak, by "holding the hands against the breast," and so into the gill-chamber through an opening in front of the chelipeds, guarded by the wide base of the epipodites of the third pair of maxillipeds. But their hands (chelae) are peculiarly shaped for this purpose, being very broad and flat, and usually having a toothed crest, which is held against the forepart of the body. Through

[1] *Key to the families of the Oxystomata.*

I. Body of the shape usual in crabs. Abdomen hidden under thorax. Antennae small. Legs normal in position.

  A. Afferent openings to gill-chambers lie in front of first pair of legs (chelipeds). Gills 9 on each side. Male openings coxal. *Calappidae.*

  B. Afferent openings to gill-chambers lie on either side of the mouth at the base of the third maxillipeds. Gills less than 9 a side. Male openings sternal. *Leucosiidae.*

II. Body more or less abnormal in shape. Abdomen not hidden under thorax. Antennae large. Last one or two pairs of legs in a more dorsal position than the rest.

  A. Carapace short. Last two pairs of legs subprehensile, with hook-like end-joints. *Dorippidae.*

  B. Carapace long. Legs usually have the last two joints very broad. *Raninidae.*

Key to the subfamilies of the Calappidae.

I. Last three joints of 3rd maxilliped not hidden by the meropodite. Orbits not separated from the antennular sockets.

  A. Meropodite of 3rd maxilliped not elongate nor acute. Exopodite of same limb with flagellum. Legs not adapted for swimming. *Calappinae.*

  B. Meropodite of 3rd maxilliped elongate and acute. Exopodite of same limb without flagellum. Legs adapted for swimming. *Orithyinae.*

II. Last three joints of 3rd maxilliped hidden by the meropodite. Orbits more or less separated from the antennular sockets. [Exopodite of 3rd maxilliped with flagellum. Meropodite of same limb elongate and acute. Legs may be adapted for swimming or not.] *Matutinae.*

Key to the subfamilies of the Leucosiidae.

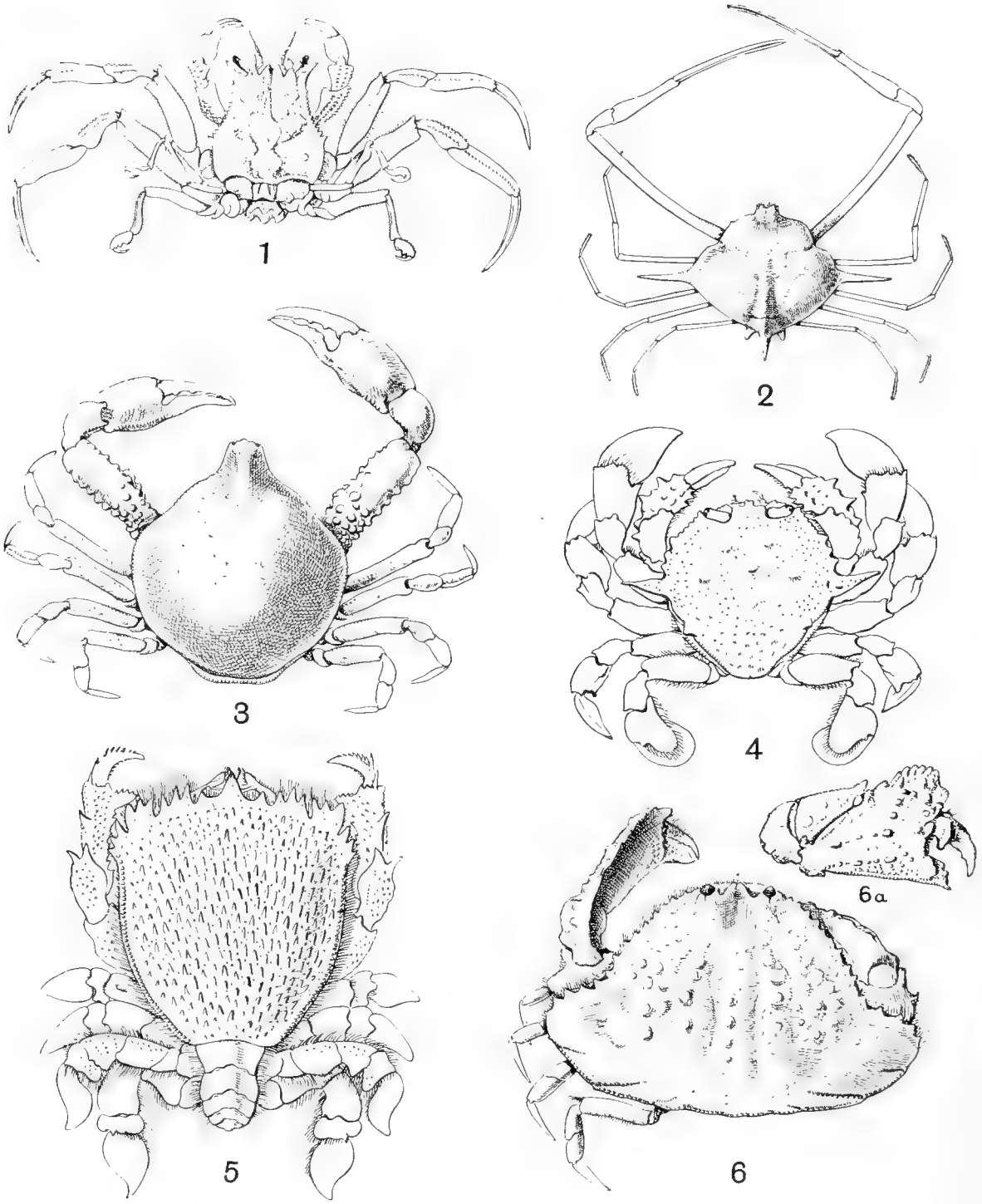
I. Meropodite of 3rd maxilliped more than half the length of the ischiopodite. Fingers stout, gradually narrowing from base to tip, usually shorter than the palm. *Leucosiinae.*

II. Meropodite of 3rd maxilliped never more than half the length of the ischiopodite. Fingers slender, of even width from the base to near the tip, usually longer than palm. *Iliinae.*

Key to the subfamilies of the Dorippidae.

I. 3rd maxillipeds leave a good part of the mouth uncovered. Inward openings to the gills near the base of the chelipeds. *Dorippinae.*

II. 3rd maxillipeds almost completely cover the mouth. Inward openings to the gills may or may not be near the base of the chelipeds. *Tymolinae.*



BORRADAILE——OXYSTOMATA.

To face p. 435.

the notches between the teeth water can enter, while at least the coarser sand-grains are kept out. *Matuta* (Pl. XXII. fig. 4) replaces these teeth, functionally, by a sieve of hairs. In the Leucosiidae, on the other hand, the openings for the ingoing stream are situated at the base of the maxillipeds of the third pair, and the water is led thither by a groove on the body, outside the efferent channel and parallel with it, covered by the third pair of maxillipeds. The Dorippidae (Pl. XXII. fig. 1) are probably divided in this respect, some breathing like the Leucosiidae, while others do not. In the Raninidae (Pl. XXII. fig. 5) a third method seems to be adopted. There are no obvious afferent openings in the forepart of the thorax, but spaces can clearly be seen between the hind edge of the carapace and the bases of the last pair of legs, and it is through these that the water probably enters.

Besides the conformation of the breathing organs just described we can trace other adaptations of the structure of Oxystomes to a sandy habitat. The comparatively simple egg- or pear-shaped body of some Leucosiidae is eminently suitable to a life spent buried in the sand, and the hard carapace found in most of these crabs is no doubt a last resource of the defenceless. *Calappa*, when seized, often draws up its legs under the broad shields formed by the overlapping edges of the carapace, thus seeming to sham death (Pl. XXII. fig. 6, right side). No doubt it is more difficult to dismember in this attitude, but it is quite possible that the action has no such special significance in this case, being instinctively adopted whenever the animal is moved against its will[1]. The colouring of many Calappidae is another feature in which they are adapted to their environment, being sand-like, and clearly protective.

Notwithstanding these generalisations, it is by no means likely that all Oxystomes hide in sand. *Dorippe* (Pl. XXII. fig. 1) conceals itself by holding a sponge or some other object over its back with its two hinder pairs of legs, which are dorsally placed and subchelate with hooked end-joints. Many of the Leucosiid genera show so strong a likeness to the Spider crabs (Oxyrhyncha) in their form of body and limbs (Fig. 117, and Pl. XXII. fig. 2) that they probably have a similar habit of weed-haunting, a view confirmed by the fact that several were taken in weed by the Expedition[2]. Another habitat is taken up by *Oreophorus* and *Tlos* (Fig. 115), which closely resemble water-worn coral pebbles, and live on shingle made up of such pebbles.

As a whole the Oxystomata are of distinctly sluggish habits, and this peculiarity reaches its height in the Leucosiidae. *Calappa* is perhaps somewhat more active. *Matuta* is not only a good swimmer, by means of paddle-like feet (Pl. XXII. fig. 4), but also an excellent digger, burying itself with wonderful rapidity in the sand. *Dorippe* is said to be able to run rapidly by means of its two pairs of very long walking-legs (Pl. XXII. fig. 1). And, lastly, the

Explanation of Plate XXII.

Fig. 1. *Dorippe dorsipes*. Fig. 2. *Arcania quinquespinosa*. Fig. 3. *Leucosia marmorea*. Fig. 4. *Matuta banksi*. Fig. 5. *Ranina serrata*. Fig. 6. *Calappa hepatica*, legs on right side withdrawn under the shield. 6 *a*, outside of hand, showing crest. The figures are not drawn to one scale.

[1] *Calappa* is generally to be found in spots where deep sand is freely exposed to currents or wave motion, and in this compact form would probably undergo rolling about on a soft bottom without much injury.

[2] In considering the habitat of Oxystomes, as of other crabs, it should always be remembered that actual observation in shallow water is far more convincing proof than dredging on any particular bottom. For instance, a large crab dredged on a bottom of coral blocks may fairly be concluded not to be a sand-haunting one, but a small species may well make use of the hollows in the blocks, often as large as a man's fist, which are found to be filled with sand, and may have been dislodged in the dredge; and, again, the presence of weed or coral in a dredging always opens the possibility that some of the crabs found free may have belonged to them.

Raninidae are probably swimming sand-crabs, somewhat like *Matuta* in habits, as they are in the shape of the legs, and moving with jerks like the Galatheidae.

Judging from the contents of their stomachs, de Haan came to the conclusion that *Calappa*, *Matuta* and *Dorippe* feed on other crabs, *Leucosia* on prawns, and *Ranina* on fish and starfish. The following systematic list includes the forms taken by the expedition. All those not now described for the first time are of Indian or Indo-pacific distribution.

Family **Calappidae.**

Subfamily **Calappinae.** Genus *Calappa* Fabr., 1798.

1. *Calappa hepatica* (Linn.), 1764. Alcock, II. p. 142. (Pl. XXII. fig. 6.)

Taken at Hulule, Male Atoll and in Minikoi lagoon down to 5 fathoms.

2. *Calappa gallus* (Hbst.), 1803. Alcock, II. p. 146.

Dredged in Felidu, Haddumati and Suvadiva Atolls in 25—43 fathoms.

3. *Calappa depressa* Miers, 1886.

Miers, Challenger Brachyura, p. 287, Pl. XXIII. Fig. 2 (1886).

Dredged in Suvadiva Atoll in 43 fathoms.

4. *Calappa pustulosa* Alc., 1896, var. See Alcock, II. p. 147.

The specimens differ from the type in that: (1) the shields at the sides of the carapace are better developed, resembling those of *C. depressa* Miers; (2) the endostomial septum is complete in its hinder half and hollowed out in its anterior half only; (3) the whole antero-lateral edge is toothed (as in Alcock's figure. In his description he says that the anterior half is smooth). The name *clypeata* would be a suitable one to apply to this variety.

Dredged in Haddumati and Mulaku Atolls, in 30—39 fathoms.

Genus *Cryptosoma* Brullé, 1837.

5. *Cryptosoma granulosum* (de Haan), 1835. Alcock, II. p. 182.

Dredged in Suvadiva and South Nilandu Atolls, in 30—43 fathoms.

Subfamily **Matutinae.** Genus *Matuta* Fabr., 1798.

6. *Matuta banksi* Leach 1817. Alcock, II. p. 158. (Pl. XXII. fig. 4.)

Taken in Hulule, Male Atoll.

Family **Leucosiidae.**

Subfamily **Leucosiinae.** Genus *Oreophorus* Rüppell, 1830.

7. *Oreophorus reticulatus* Ad. and Wh., 1850. Alcock, II. p. 174.

Besides a full-grown male, there is in the collection a very small one which closely resembles the adult, and is not at all like the specimen figured by Adams and White as the young of this species ["Samarang" Crustacea, Pl. VI. Fig. 2].

Dredged in Kolumadulu and Fadifolu Atolls in 38 and 23 fathoms.

Genus *Tlos* Ad. and Wh., 1850.

8. *Tlos latus* n. sp. (Fig. 115).

Diagnosis: "A Tlos with the carapace broad and finely granulated all over, roughened by small pits and minute linear grooves among the granules; in the hinder part a mound, consisting of two large humps, one on each side of the cardiac region, and the latter region itself somewhat swollen, and connected with the front by a broad ridge, on each side of which is a deep pit; the front well developed, notched at the tip, not quite hiding the eyes; the anterolateral edge with one peak, the posterolateral irregular; the chelipeds about a third longer than the carapace in the female, irregularly nodular all over; the walking-legs short and nodular."

Length: 6 mm. Breadth: 9 mm. Colour in spirit, white.

Taken at Hulule, Male Atoll, and dredged in 35 fathoms in North Male Atoll.

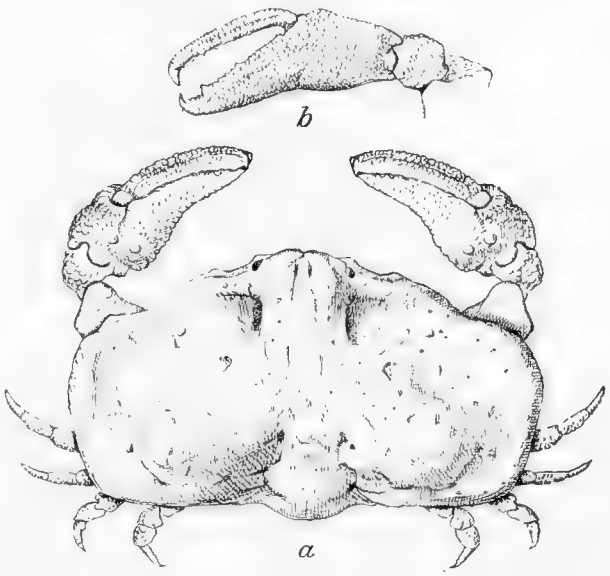


Fig. 115. *Tlos latus*; *a*. whole animal, *b*. outside of hand.

Genus *Ebalia* Leach, 1817.

9. *Ebalia erosa* (A. M.-Edw.), 1873. Alcock, II. p. 189.

Taken in Minikoi lagoon down to 9 fathoms and in Fadifolu Atoll in 22 fathoms.

10. *Ebalia maldivensis* n. sp. (Fig. 116).

Diagnosis: "An *Ebalia* with the carapace somewhat broader than long; the front prominent, rather deeply bilobed; the anterolateral edge with three projections, of which the hindermost is the smallest; the middle region of the carapace raised above the rest, bearing a large mound in the hinder part and a horseshoe of 8 smaller mounds in front, the smaller mounds varying greatly in distinctness in different specimens; the hind edge evenly arched; the body and limbs granular all over; the chelipeds of simple shape, without thorns or teeth, the fingers slender, grooved, as long as the somewhat swollen palm."

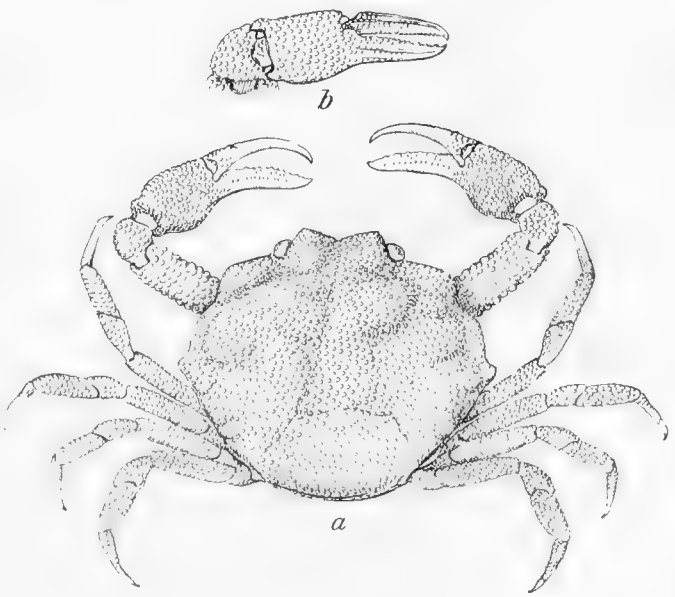


Fig. 116. *Ebalia maldivensis*; *a*. whole animal, *b*. outside of hand.

Length: 4·5 mm. Breadth: 5 mm. Colour in spirit, white, tinged in places with yellow. Dredged in Suvadiva and Fadifolu Atolls in 43 and 23 fathoms.

Genus *Leucosilia* Bell, 1855.

11. *Leucosilia maldivensis* n. sp. (Fig. 117).

Diagnosis: "A *Leucosilia* with the carapace subcircular, covered with flattened granules which in the branchial regions pass into minute, flat-topped spines; the front short, barely hiding the epistome; a large hollow in the carapace on each side just behind the front and a ridge separating these hollows and running back to the gastric region, where it bears 5 knobs, 2 knobs one behind another on the cardiac region, and a blunt knob at each end of the hind margin; the chelipeds about $\frac{1}{2}$ as long again as the carapace, granular, the granules being smallest on the hands, the fingers longer than the palms, furrowed, slender, and set with slender teeth of various sizes; the walking-legs short and slender, with long end-joints."

Length: 12 mm. Breadth: 11 mm. Colour in spirit, white.

Dredged in Suvadiva Atoll, in 43 fathoms.

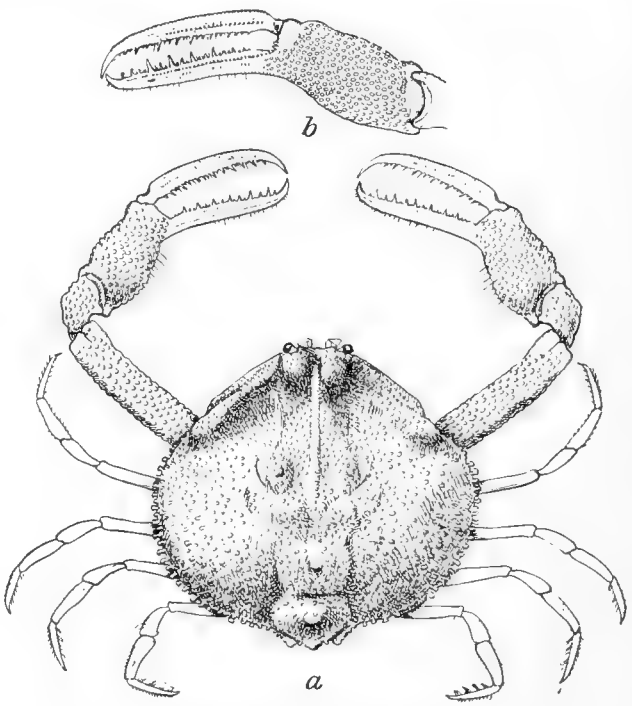


Fig. 117. *Leucosilia maldivensis*; *a*. whole animal, *b*. outside of hand.

Genus *Myra* Leach, 1817.

12. *Myra brevimana* Alc., 1896. Alcock, II. p. 206.

Dredged in Kolumadulu and South Nilandu Atolls, in 35 and 36 fathoms.

13. *Myra darnleyensis* Hasw., 1879. Alcock, II. p. 207.

Dredged in Suvadiva, South Nilandu and Mulaku Atolls in 28—43 fathoms.

14. *Myra intermedia* n. sp.

A specimen of a new form of *Myra* in the collection shows a combination of characters which tend to unite the species *M. fugax* (Fabr.), *M. affinis* Bell, and *M. brevimanus* Alc.

The following are the diagnostic features of the new form: (1) Carapace rather sparsely covered with granules, which are smaller than in *M. brevimana* except on the intestinal region and the base of the large hinder spine, where they are coarse and close set. (2) A keel is present in the middle of the back and is more closely granular than the field on either side of it. (3) The tooth on the hinder part of the upper of the two lines which define the hepatic facet is almost lost. (4) The front hardly projects to the same level as the

outer tooth of the breathing channel; it is widely, but not very deeply, notched. (5) All the three spines at the hinder end are sharp. The middle one is much the longest and is somewhat upcurved at the tip, which is free from granules. (6) There is no tooth at the end of the long segment of the male abdomen. (7) The length of the male cheliped : length of carapace (without spine) :: 5 : 3. The palm is short, and the moveable finger almost exactly equals the outer edge of the palm in length.

The specimen is a male 15 mm. long without the spine and is probably full-grown. The colour in spirit is dirty white. It was dredged in 30 fathoms in Mulaku Atoll and probably taken from a sponge.

Genus *Leucosia* Fabr., 1798.

15. *Leucosia marmorea* Bell, 1858. Alcock, II. p. 221. (Pl. XXII. fig. 3.)

Dredged in Felidu and Mulaku Atolls in 25 and 40 fathoms.

16. *Leucosia* sp. aff. *pallida* Bell, 1855. See Alcock, II. p. 222.

A damaged male specimen of a *Leucosia* from Hulule resembles *L. pallida* in the shape of the carapace, but differs in that: (1) the front has the middle tooth broad and slightly emarginate at the tip. (2) The crenulation of the anterolateral edge is almost obsolete. (3) The outer limb of the V-shaped thoracic hollow is obsolete.

Genus *Pseudophilyra* Miers, 1879.

17. *Pseudophilyra pusilla* Hend., 1893. Alcock, II. p. 281.

The markings on the carapace are irregular and do not agree with Alcock's description. In particular the brown band across the tip of the front is wanting. The palms are somewhat longer and flatter than in Henderson's figure [*Tr. Linn. Soc.* (2) v. *Zool.*].

Dredged in Minikoi, South Nilandu and Suvadiva Atolls in from 2 to 43 fathoms.

Subfamily **Iliinae.** Genus *Nursilia* Bell, 1855.

18. *Nursilia dentata* Bell, 1855. Alcock, II. p. 260.

Dredged in South Nilandu, Kolumadulu, Suvadiva and Mulaku Atolls in various depths down to 40 fathoms.

Genus *Arcania* Leach 1817.

19. *Arcania tuberculata* Bell, 1855. Alcock, II. p. 268.

Dredged in South Nilandu Atoll in 30 fathoms.

20. *Arcania quinquespinosa* Alc. and And., 1894. Alcock, II. p. 266. (Pl. XXII. fig. 2.)

Dredged in Haddumati, Kolumadulu and Suvadiva Atolls in various depths down to 44 fathoms.

Family **Dorippidae.** Genus *Dorippe* Fabr., 1798.

21. *Dorippe dorsipes* (Linn.), 1764. Alcock, II. p. 277. (Pl. XXII. fig. 1.)

The specimen carried a sponge when taken. It was dredged in Haddumati Atoll in 40 fathoms.

VII. THE BARNACLES (CIRRIPEDIA).

Seeing that the Barnacles are sessile animals, and need to attach themselves to a firm holdfast, it might be expected that they would be numerous and characteristic inhabitants of coral reefs, which give so many opportunities of settlement on fixed bodies, under conditions so diverse both biologically and physically. But, curiously enough, as Darwin has remarked[1], coral reefs are, for some reason, not favourable to them. Yet a number of species may be taken there, and some are even characteristic and specially modified for the habitat. Among these may be included the *Lithotryas* which bore into coral rock, those species of *Pyrgoma* which live imbedded in reef corals, and several of the *allium*-group of *Balanus*, besides common species such as *B. tintinnabulum* and *B. amphitrite*. Of course those which live on animals such as sea-snakes or turtles and on floating objects as cuttle-bones or pieces of wood, are also found.

The collection contains 16 species, including members of all the groups mentioned above. Of these species two are new. Most of the others have already been recorded from some part of the Indo-Pacific region, but one form can only be classed as a variety of the West Indian *Lithotrya dorsalis*, and another, whose locality has hitherto been unknown, was formerly supposed to be (and still may be) West Indian.

Family **Lepadidae.**

Genus *Lepas* Linn., 1758.

1. *Lepas ansifera* Linn., 1767. Darwin, I. p. 81[1].

Taken on floating objects in various localities throughout the Archipelagoes, a number of the younger individuals being on cuttle-bones.

Genus *Dichelaspis* Darw., 1851.

2. *Dichelaspis warwicki* (Gray), 1825. Darwin, I. p. 120.

The specimens differ from that figured by Darwin in that the upper end of the occludent segment of the scutum is considerably wider than the base of this segment, leaving only a narrow strip of soft skin between itself and the basal segment. But Darwin says that this segment may be wider in the upper part. The plate at the base of the carina is an independent ossicle, joined by a suture to the true keel.

Taken in Suvadiva Atoll.

3. ? *Dichelaspis grayi* Darw., 1851. Darwin, I. p. 123.

A specimen which I believe to belong either to this species or to *D. pellucida* Darw., 1851, is attached to a sea-snake (*Hydrus platurus*) taken by the expedition in the Maldives.

Unfortunately, the shells are so badly preserved, owing to their having been kept in formalin, that it is impossible to be certain of the species. It is the habit of both species to live on sea-snakes.

[1] All the references to Darwin's work in this paper are to his "Monograph of the Cirripedia," London, 1851–4.

Genus *Conchoderma* Olfers, 1814.

4. *Conchoderma hunteri* Darw., 1851. Darwin, I. p. 153.

Hoek ("Challenger" Cirripedes) regards this form as a variety of *C. virgata* (Spengler), 1790, but the latter has not been found on sea-snakes, while *C. hunteri* appears to have that habitat, Darwin's specimen and the present both so occurring. The only others recorded (Stebbing, Willey's *Zool. Results*, vol. v. p. 676) made the pardonable mistake of attaching themselves to submarine cables. This fact lends support to the presumption that the species are distinct.

Genus *Lithotrya* Sowerby, 1822.

5. *Lithotrya dorsalis* (Ellis), 1786. Darwin, I. p. 351.

I am unable to regard the Maldive specimens of this genus otherwise than as belonging to varieties of this West Indian species. Two forms may be recognised, the type (var. A) not being present.

B. Var. *maldivensis* n.

Differs from the type in the following points: (1) There is a very faint ridge within the carina. (2) The caudal appendages are rather less than half as long again as the last pedicel. (3) There is a shallow notch on the maxilla of the right side, though none on the left. (4) The tergal edge of the scutum is slightly concave. (5) The scuta are longer than in *L. dorsalis*. (6) The *carina* is shorter.

These latter two features, however, may well be due to a difference in the manner in which the specimens have become worn by the sea.

C. Var. *rugata* n.

Differs from the preceding variety in the following points: (1) The carina has a fairly strong ridge. (2) The caudal appendages are only very slightly longer than the pedicel of the last limb. (3) The rostrum is bordered by 6 scales instead of 3.

This species lives on the under side of overhanging coral rocks and is always so placed that its capitulum is at the opening of the hole. I am at a loss to understand how some of Darwin's specimens came to be reversed. For some remarks on its importance in the disintegration of coral rock, see Mr Gardiner's Paper in Part III. of this publication (p. 337).

Family **Balanidae.** Genus *Balanus* Da Costa, 1778.

6. *Balanus tintinnabulum* (Linn.), 1758. Darwin, II. p. 194.

The specimens, which were taken in various localities, are all small and belong to the var. *communis*.

7. *Balanus amphitrite* Darw., 1854. Darwin, II. p. 240.

The specimens are coloured pink and much resemble *B. tintinnabulum*. They are small and have given me much trouble, but I have finally placed them here on account of the undoubted absence of pores from the radii, and because the mandibles agree best with Darwin's description for this species. They were taken in Fadifolu Atoll.

8. *Balanus quadrivittatus* Darw., 1854. Darwin, II. p. 284.

Taken in Miladumadulu Atoll.

9. ?*Balanus terebratus* Darw., 1854. Darwin, II. p. 288.

I am unable to find in my specimens the rows of holes between the ridges of the basis as described by Darwin. Possibly the species is distinct. The scuta and terga, which were wanting in Darwin's specimens, have the following characters in mine:

Scuta. Shape that of a right-angled triangle with convex base. Growth ridges on the outside curved. Adductor ridge strong and articular moderate.

Terga. Spur very short and fairly broad. Growth ridges on the outside curved. Spur groove wide, shallow. Apical tooth present, but broken in the specimen.

Taken on the reef at Naifaro, Fadifolu Atoll.

10. *Balanus maldivensis* n. sp. (Fig. 118).

Diagnosis: "A *Balanus* with solid walls, the basis, radii and parietes being without canals, though indications of these are seen in the parietes when the latter are broken; the opening rhomboidal, and toothed owing to the projection of the tips of the parietes, the walls gnarled and often ringed, but not regularly ribbed; the scutum of simple, obtuse-angled triangular shape, with slight articular and no adductor ridge; the tergum very broad with a rounded tip, a short, broad spur, which is also rounded at the end, a sharp tooth at the end of the scutal edge next the spur, and a sharp, though not very deep, spur groove; the outside of both scutum and tergum moderately strongly ridged; the mandible with seven teeth, which grow smaller in succession from above downwards, and of which numbers 1—5 are blunt and often subdivided, while 6 and 7 are sharp, a row of stiff bristles along the lower edge and the sides and upper edge hairy; and the edge of the maxilla almost straight, without notch or projection."

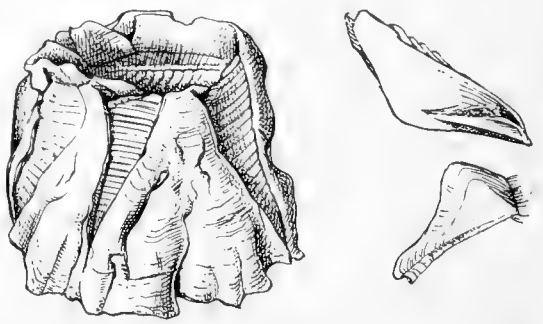


FIG. 118. *Balanus maldivensis*; whole animal, with scutum and tergum detached and seen from the inside.

Length of longest specimen: 7 mm. Height: 6 mm.

Taken in S. Nilandu Atoll, on a twig of wood.

The peculiarities of the shell of this species would appear to necessitate the founding for it of a new section [H] of the genus, with the characters: "All parts of the shell present, heavy, and without pores."

Genus *Acasta* Leach, 1817.

11. *Acasta sulcata* Lam., 1818. Darwin, II. p. 310.

Dredged in two fathoms in Fadifolu Atoll.

Genus *Pyrgoma* Leach, 1817.

12. *Pyrgoma cancellatum* Leach, 1824. Darwin, II. p. 362.

Darwin did not know from what locality his specimens of this species had been brought, but supposed it to be the West Indies. The present specimens were dredged in Suvadiva Atoll in 26 fathoms.

13. *Pyrgoma grande* (Sowerby), 1839. Darwin, II. p. 365.

This species lives inside the polyps of *Euphyllia*. The outside of the basal cup of the cirripede often shows septa formed by the polyp, so that it would appear that the soft parts of the polyp adapt themselves to the invasion by growing over the foreign body. [The same or another species lives commonly in the Maldives on *Galaxea*. ED.]

Darwin reports *P. grande* from "two sorts of corals," and it is evident from his figure that in at least one of these the same relation between the barnacle and the coral is found as in our specimens.

14. *Pyrgoma madreporae* n. sp. (Fig. 119).

Diagnosis: "A *Pyrgoma* with the shell flat, oval, the opening keyhole-shaped; the ridges well developed, alternately long and short, rather wide apart, about 11 in a quadrant, projecting somewhat at their outer ends; basal cup very strongly ribbed inside; scutum of simple, triangular shape, with a rounded basal edge and a well-developed adductor ridge; tergum also triangular, with a short spur; cirri delicate, the series growing longer from before backwards; mandible with 5 teeth, exclusive of the lower angle, which bears a number of bristles, the teeth growing smaller from above downwards."

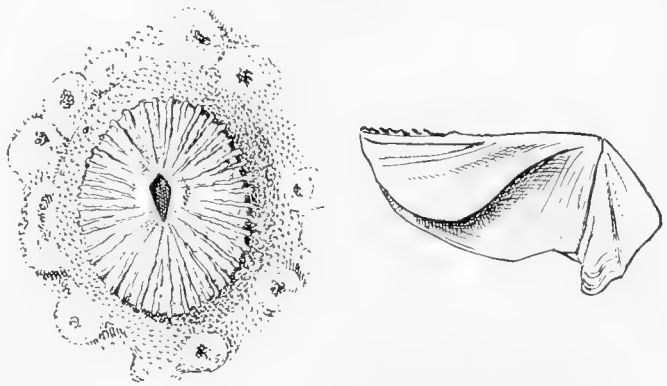


FIG. 119. *Pyrgoma madreporae*; whole animal imbedded in coral, with detached scutum and tergum seen from the inside.

Breadth of largest specimen: 8 mm. Colour in spirit, white.

Found in a *Madrepora* at Hulule, Male Atoll.

Genus *Chelonobia* Leach, 1817.

15. *Chelonobia testudinaria* (Linn.), 1758. Darwin, II. p. 392.

Two specimens were taken on the carapace of the turtle *Chelone midas* in Minikoi.

16. *Chelonobia caretta* (Spengler), 1790. Darwin, II. p. 394.

Several specimens were found in the skin on the legs of the turtle *Chelone imbricata* in Minikoi.

MARINE CRUSTACEANS.

VIII. STOMATOPODA, WITH AN ACCOUNT OF THE VARIETIES OF GONODACTYLUS CHIRAGRA.

By W. F. Lanchester, M.A., *King's College, Cambridge.*

(With Plate XXIII.)

I. ADULT FORMS.

The adults in this collection all belong, with the exception of two specimens of *Pseudosquilla ciliata*, to the genus *Gonodactylus*; moreover they should be included in a single species of that genus, namely, the world-wide *G. chiragra*. On first being sorted out these *Gonodactylus* fell fairly readily into three groups, (*a*) representing the *G. chiragra* of most authors (not of Fabricius, to which point I shall return later), (*b*) representing the *G. glabrous* of Brooks, and (*c*) seven specimens representing the *G. spinosus* of Bigelow. Closer examination, however, revealed in each of the first two groups a considerable amount of variation, chiefly in respect to the characters of the 6th abdominal segment and the telson, that is to those which more particularly distinguish the two forms: and in seeking to group these variable forms I was led insensibly to the conviction that no hard-and-fast line could be drawn between the two species, and that Brooks was right in his estimate, which I did not see till later, that "future discoveries may reveal so many transitional forms that the sharp lines between the species" (including a third, the *G. graphurus* of Miers) "will break down" (Chall. *Stom.* p. 64). The third group, that of *G. spinosus*, numbers but few specimens, and therefore presents little evidence of variation.

The great preponderance of this species in the Maldives and Laccadives is a striking fact, for which, unfortunately, no explanation can at present be forthcoming. A partial explanation lies in the fact that these forms are found on the surface of the reefs, or sea-bottom, whereas the genus *Squilla*, so conspicuous by its absence in this region, and yet one of the commonest forms of Stomatopods in the Indo-Malaysian region, lives in burrows in the sand or mud, from which it is a matter of some difficulty to dig it out even when the burrows are uncovered at low water, while it renders it unlikely that many will fall victims to the dredge. But this is only the smallest part of the question; for Mr Stanley Gardiner has assured me that he used every effort to obtain *Squilla* from holes at low water, so that we may feel certain that, had the genus existed in any quantity at all,

there would have been a few specimens at least in the collection. And without going so far as to say that the genus *Squilla* is quite unrepresented in this locality, it is yet sufficiently obvious that, for some reason, the conditions are more suitable generally to *Gonodactylus chiragra*. The bathymetric distribution, so far as this collection is concerned, ranges from littoral to 44 *f.* (fathoms).

1. *Gonodactylus chiragra* (Fabr.) Herbst.

Fabricius, *Spec. Insect.* p. 515 (1781), *Mant. Insect.* p. 334 (1787), *Ent. Syst.* III. 1, p. 513 (1793), and *Ent. Syst. Suppl.* p. 417 (1798): Herbst, *Cancer* (*mantis*) *chiragra, Krab. u. Krebs.* II. p. 100, Pl. XXXIV. Fig. 2 (1796): M.-Edw., *Hist. Nat. Crust.* II. p. 528 (1837): Dana, *U.S. Expl. Exp. Crust.* p. 623, Pl. XLI. Fig. 5 (1852): Heller, *Novara-Reise, Crust.* p. 126 (1865): v. Martens, *Arch. f. Naturg.* 38, p. 147 (1872): Miers, *Ann. Mag. Nat. Hist.* (5) v. p. 118, 1880: Brooks, '*Challenger*' *Stomatopoda*, p. 56 (1886), *G. glabrous, id.* p. 62, Pl. XIV. Fig. 5, Pl. XV. Fig. 7: Henderson, *Trans. Linn. Soc. Zool.* (2) v. p. 454 (1893): *G. glaber, id. loc. cit.*: Bigelow, *Proc. U.S. Nat. Mus.* XVII. p. 494 (1894): *G. spinosus, id. l.c.* p. 493: Hansen, *G. oerstedii, Plankton-Exp. Isop. Cumac. u. Stomatop.* p. 65 (footnote) (1895): Borradaile, *Proc. Zool. Soc.*, p. 32, Pl. VI. Fig. 8 (1898): *G. espinosus, id.* p. 35, Pl. V. Fig. 5: *id.* Willey's *Zool. Res.* Pt IV. p. 400 (1900): de Man, *Zool. Jahrb. Syst.* X. p. 694 (1898): Nobili, *G. festae, Boll. Mus. Zool. Torino*, XVI. p. 53 (sep. copy 1902).

The synonymy of this species is, at present, rather confused, owing, no doubt, to the considerable range of variation exhibited by it, and it is unfortunate, from one point of view, that Fabricius is not sufficiently detailed in his description of that part of the animal, viz. the 6th abdominal segment and the telson, which presents so much variation; the rest of his account is particularly clear and complete. This full description is to be found twice, once in the *Species Insectorum* (1781) and again, with but slight alteration, in the *Entomologia Systematica* (1793); in his other two works he refers to it only with a brief diagnosis. What he has to say about the hinder part of the animal is the same in both cases:— "Abdomen...decimo segmento lineis sex elevatis spinosis, ultimo lineis elevatis spinosis margineque postico spinis serrato." Now the latter part of this may signify one of two things. Either it may mean that the three carinae of the dorsal surface are "raised and spinous" while the posterior border is "serrated with spines" corresponding to the four or six *marginal* spines[1]; or it may be that the words 'lineis elevatis spinosis' refer to the four or six marginal spines with their forwardly-running carinae, while the spines with which the hinder border is serrated may be the numerous small spines between the marginals[2]. In the *Spec. Ins.* and the *Ent. Syst. Suppl.* Fabricius refers his species to the *Squilla arenaria marina* of Rumphius, and examination of Rumphius' plate renders it more likely that the second of the two alternatives is correct, since the dorsal carinae are not represented as spinous. Fabricius' type specimens do not, so far as I know, now exist; there are, at any rate, no examples of Stomatopods in the collection of his types at the Kiel Museum, as I am informed by Dr Immermann of that Museum, who very kindly examined the specimens preserved there for me. Accordingly it is quite impossible to decide which variety Fabricius was dealing with, though, as there is no doubt he had at least one of the varieties of this animal before him, there is no difficulty about retaining his specific name. I pass now to the consideration of the forms described by succeeding authors:—

[1] Corresponding to var. *smithii* or var. *glabrous*. [2] Corresponding to any variety of the species as a whole.

1796, Herbst. Figure very poor. Text:—"Das letzte Glied hat solcher Erhöhungen drey, und einen breiten, platten, Rand der durch Einschnitte *viermal* gezähnt ist." (Italics mine.) Corresponds with my variety F below.

1837, M.-Edwards. Text:—"Abdomen...son dernier article surmonté de six gros tubercules alongés et son dernier segment...portant *trois ou cinq* tubercules alongés *très arrondies*, et armé de dents marginales courtes, larges, et renflées." (Italics mine.) The presence of "three or five" tubercles on the telson is interesting as showing that Milne-Edwards had before him examples both of var. F mihi and var. *glabrous* Brooks (or var. *graphurus* Miers) and yet did not distinguish them as species; in fact he adds, at the end of his description, and after giving a long list of localities to show the world-wide distribution of the species, "du moins je n'ai pu découvrir aucune particularité constante pour distinguer entre eux les individus venants de ces parages éloignés." The absence of any mention of the 'anchor,' and the fact of the ridges being very swollen (très arrondies) renders it probable, though not absolutely certain, that his forms with three ridges correspond with my var. F.

1852, Dana. The lateral marginal teeth and the anchor are not shown in the figure. Corresponds to var. F.

1865, Heller. A small specimen, 20 mm. long, badly preserved. Text:—"Das letzte Segment dreieckig, stark gewolbt, in der Mitte mit *einen scharf* Längskiele versehen, der nach rückwärts mit *einem kleinem Stachel* endet, nach beiden Seiten hin dachförmig, glatt; die Ränder jederseits mit drei Zähnen bewaffnet." (Italics mine.) The presence of only one ridge is due to the small size of the specimen, without doubt; although the lateral ridges are generally visible even in smaller specimens than Heller's, they are sometimes obscure (or possibly absent) in individuals of 20 mm., though this is not usual. The sharpness of the median keel, its termination in a spine, and the presence of lateral marginal teeth point to the specimen being a young var. *smithii*.

1872, von Martens. Pointed out evidence of considerable variation in the presence or absence of spines. It is not apparent which variety his specimens correspond to.

1880, Miers. In this his well-known work "On the Squillidae" Miers has given a full description of our species: the only points which concern us are in regard to the telson, which in his forms has three swollen spineless carinae, the middle one without an anchor and no lateral marginal teeth. For two reasons in particular I have chosen this as the type, firstly, because it is the form of Herbst who described the species shortly after Fabricius, and also the form of the great majority of authors after him; and secondly, because it is the form from which most of the varieties with which I shall deal appear to have taken their origin. Dr de Man in 1898 selected the spineless anchor-form as the type, but he gave no reason for so doing, and it is extremely improbable that Fabricius' types corresponded to this form at all: anyhow in the absence of evidence as to Fabricius' types we are justified in taking Herbst's form as the type of the species. The type then corresponds with my variety F.

1886, Brooks, and 1893, Henderson. Follow Miers. 1894, Bigelow. In his key to the species of *Gonodactylus* Bigelow makes it quite clear that his *G. chiragra* is identical with the type. 1898, de Man. His type form corresponds with my variety *incipiens* b = var. A. 1900, Borradaile. Has followed de Man. I have adhered to the system of lettering introduced by him, so that his var. A and mine correspond, as do the rest of the varieties lettered by him.

Turning now to the different varieties of *G. chiragra*, as now defined, afforded by this collection and the accounts of earlier authors, I must premise that I find it necessary to deal with them under three headings, the first two concerning those varieties which connect with each other by greater or lesser transitions of structure, the third concerning those which do not fall so readily into a transitional scheme. It will be easily understood that by the very nature of the case the exact definition of the different varieties must be a matter of considerable difficulty, that it would be open to any other observer, by a re-shuffling of the cards, so to speak, to form a scheme differing, in detailed arrangement, from the one now given, and that such a scheme cannot pretend as yet, while the material, and the information on this material, are still so comparatively limited, to represent with any certainty the *genetic history* of the forms in question.

First heading. I. Var. *tumidus* var. nov. Pl. XXIII. figs. 1 and 1 *a*.

This is that form of *G. chiragra* which has been taken by most carcinologists to be the type of the species, in which there are three much swollen carinae, without spines, on the telson, and no lateral marginal teeth. To this should be referred the examples described or figured by Herbst, Milne-Edwards (*partim*), Dana, von Martens, Miers, Brooks, Henderson, Bigelow, Borradaile. Although the absence of the lateral marginals is characteristic of this variety, yet sometimes traces of these teeth may be seen, as in the case of Fig. 1, and it is worth noting that the tooth is more prominent on the one side than the other; in a second specimen the teeth are absent, and in a third the rudiments of teeth are equal.

3 ♂♂, length 61·5, 48·5, and 44·5. Minikoi; with the following note:—"variegated green and white. The dark patches on the last thoracic segment and 5th abdominal segment are very characteristic; latter orange-red in centre." From the reef.

II. Forms connecting var. *tumidus* with III. var. *acutus*. Pl. XXIII. fig. 2.

The carinae are distinctly less swollen, especially the median. No lateral marginals.

1 ♂, length 42·5, and 2 ♀♀, 50 and 43, Minikoi. From the reef.

III. Var. *acutus* var. nov. Pl. XXIII. figs. 3 and 3 *a*.

The three carinae are now sharply defined, and the distal end of the median carina drops almost vertically so as to appear angular, rather than rounded and sloping as in var. *tumidus*. No lateral marginals.

3 ♀♀, length 38·5, 37, and 39, Minikoi, with the same note as that applying to the specimens of var. *tumidus*, and 2 ♀♀, length 62·5 and 15, Minikoi. From the reef.

IV. Var. *smithii* Pocock. Pl. XXIII. figs. 4 and 4 *a*.

Carinae sharp, the median with a well-defined terminal spine. Lateral marginal teeth present.

1 ♂, length 22, Hulule, Male Atoll, Maldives. From the reef.

To this form belongs a specimen referred by me to var. *smithii* Pocock in the *Proc. Zool. Soc. London*, 1900, p. 555; also three specimens referred by Borradaile to the same variety from Rotuma. In the latter's examples there are no signs of backwardly-directed carinae proceeding from the base of the spine of the median carina; in my two specimens, however, these can just be seen (cf. fig. 4), and this form clearly leads on to

V. Pl. XXIII. fig. 5 with which it may be included, and which differs from it only in the definite presence of carinae proceeding from the base of the spine, and forming an 'anchor.'

3 ♂♂, length 29, 30·5, and 18, and 3 ♀♀, 51·5, 36, and 27·5. Hulule, Male Atoll, Maldives. From the reef.

This is the type of var. *smithii* as figured by Pocock.

VI. Var. *segregatus* a. var. nov. Pl. XXIII. fig. 6.

This variety is very similar to var. *smithii*, but has the carinae slightly more swollen, with the spine not quite so prominent, and the flukes of the anchor separated from the base of the spine, and forming two low carinae extending not more than halfway along the sides of the median carina.

4 ♀♀, length 13, 12, 11, and 9, Goidu, Goifurfehendu Atoll. From the reef; 1 ♂, 9·5, South Male Atoll, 25 *f.*; 1 ♀, 17, Minikoi, from the reef; 1 ♀, 7·5, Hulule, Male Atoll, from the reef; and 1♀, 12, South Nilandu Atoll, 25 *f.*

It will be seen that the representatives, in this collection, of this variety are all of comparatively small size, and the imperfection of the anchor might be due to this fact. But I have also seen similar examples, in the collection of the Natural History Museum at S. Kensington, from the Macclesfield Bank, eight in number, and ranging from 20 to 30 mm. in length; while some specimens from the 'Skeat' collection of Crustacea, which differ only in the absence of the spine on the median carina, but agree in the separation of the flukes of the anchor, and to which I shall refer later, range from 20 to 28 mm. in length.

VII. Var. *segregatus* b. Pl. XXIII. figs. 7 and 7 *a*.

Some small specimens, quite similar to var. *segregatus*, but the separated flukes of the anchor, or sometimes one only on one side, bear a small spine at their distal extremity; this I should include under var. *segregatus*.

1 ♀, length 18·5, North Male Atoll, 27—35 *f.*; and 1♂, 17·5, and 4 ♀♀, 14·5, 13, 12, and 7·5, South Nilandu Atoll, 19 *f.*

VIII. Var. *glabrous* Brooks. Pl. XXIII. figs. 8, 9 and 15.

This includes the *G. glabrous* of Brooks and *G. glaber* of later authors, together with some additional forms to which reference will be made below (p. 451). On this variety it will be necessary to make some preliminary remarks before attempting any description of it, and in these remarks I shall deal with the variety as a whole, although I have, from the point of view of the transition scheme, separated off a portion of it under the second heading as in the case of var. *segregatus*. Now in dealing with the specimens of this variety in the collection I found that, though I could distinguish two extremes of structural form readily enough, yet I could not separate the individuals into two groups corresponding with these extremes, the intermediates between the two being relatively numerous and presenting all grades of slight structural differentiation. And, in spite of the smallness of the number before us, it seems to me legitimate to infer, from the evidence as it stands, that we have here a case of a Continuous (or Normal) Variation; and in fact that, different though the two extremes are structurally, yet they cannot be considered as varieties in the strict sense of the word, in face of the intermediates which exist between them. I must not, however, be taken to underrate the danger of arguing from such a small number of specimens; the facts

in the present instance do not prove, they only point to, the presence of Continuous Variation: but I do maintain (and the more I have examined the specimens, the more has my conviction been strengthened) that such evidence as there is compels us, for the present at any rate, to recognise that the Variation within the variety is Continuous. The actual proof of this point must depend on the examination of a very large number of specimens; and it seems to me that, when this examination has been made, it will be found to confirm the opinion suggested by the more slender evidence at present at our command. Assuming then that we have here Continuous Variation, or considering any other case in which we know we have similar variation, it seems desirable that the two extremes in such a case which, if the variation were Discontinuous, would be designated as *varieties*, should also be denoted by some analogous expression. For purposes of general discussion, of course, a precise word is not absolutely necessary, some such expression as 'the two extremes.' expressing the point at issue sufficiently clearly; and it is equally possible to distinguish the two extremes as 'high' and 'low' respectively (cf. Bateson's *Materials*, pp. 39—40). But the practical convenience of the systematist often requires a definite symbol by which to designate a form he is describing; it would not be enough, for instance, that he should designate a specimen var. *glabrous* without specifying whether it is one or other extreme of that variety, or one of the intermediates. Of course it is not possible to sum up any given intermediate in a word, but the extremes give us fixed points on which we may rely. I propose, therefore, to use the word **'term'** to express the extremes of structural type manifested in a Continuous Variation, and for purposes of systematy, it is only necessary to qualify the word by the addition of, say, an alphabetical letter to distinguish the one term from the other. For the word itself I would point out that it is brief, it is Latin in origin, that in its primary meaning it expresses what it is wished to express, namely the existence of "ends" to a series, and lastly but not leastly it is quite neutral, suggesting no more than it is meant to suggest. The expression 'end-form' is excluded by reason of the special meaning recently attached to the word 'form'; the word 'extreme' on the other hand is of so much use for general purposes that it would only make confusion to give it a special meaning (as indeed has happened now in the case of the word 'form'). 'End-term' suggested itself, but is, after all, tautologous. The words 'high' and 'low' have been already used by Mr Bateson in a special sense, applying to the ends of a Discontinuous series in the case of the males only of a species; moreover they imply degree of variation.

Assuming, then, the use of this word, two points call for special comment. Firstly, it is plain that the use of the word can be of no help in the cases where it is an intermediate that is being referred to, and as by the nature of the case, the intermediates are more numerous than the terms, it may be objected that the word will have but a very limited value. This is true, but the value, limited though it be, seems to me a real value. The fact that we cannot express by a word the differences between the intermediates does not alter the fact that we can so express the often great structural differences between the two extremes. Were two genera to be found to be united by a continuous series of intermediates the series would form a single genus and species, but it would none the less be convenient to designate the extremes, with their great structural differences, by some special word, even though we could not do the same in the case of any given intermediate which also differed greatly from one of the extremes.

Secondly, it is always possible that, though in a given series two extremes may be distinguished as 'term *a*' and 'term *b*,' later research may show one or the other not to be

the real term. In this case, however, I see no difficulty in transferring the term, whether '*a*' or '*b*,' to its proper position, the original term falling then into its proper place as an intermediate.

Turning now to the present instance, I should describe the variety as follows:—

var. *glabrous* Brooks.

Five dorsal carinae on the telson, all of which are well-developed; these carinae are either sharp or tumid, and the middle three may or may not terminate in spines. This variety is subdivided into

1. Term *a*. Carinae sharp, with spines on the three middle ones. This I take to be exemplified by the specimen figured by Brooks (Chall. *Stomatopoda*, Pl. XIV. Fig. 5). There are no true examples of this in the collection.

2. Term *b*. Carinae very swollen, so as to touch one another, without spines. This is the form shown under fig. 15 in my Plate.

One male from Goidu; length 34.

3. Intermediates between these. Four of these show a connection, or traces of a connection, between the median and submedian carinae (cf. figs. 8 and 9).

Numerous examples. Goidu, Goifurfehendu Atoll; Hulule, Male Atoll; Furnadu Velu, Miladumadulu Atoll; Naifaro, Fadiffolu Atoll; all from the reef. Minikoi, "obtained by breaking up a coral mass from the outer reef." Miladumadulu Atoll, 3 *f*. South Male Atoll, 5 *f*.

IX. Var. *mutatus*.

The carinae are very swollen, but the middle three carry spines. 1 ♂ 32, and 1 ♀ 39, Furnadu Velu, Miladumadulu Atoll; 1 ♀ 20, Hulule, Male Atoll; 2 ♂♂ 27, and 21·5, and 1 ♀ 30, Goidu, Goifurfehendu Atoll.

X. Var. *graphurus* Miers.

Closely similar to var. *mutatus*, but distinguished by the presence of sutures on the abdominal terga.

A further distinction between *G. glabrous* and *G. graphurus*, namely the presence of a low *median* carina on the 6th abdominal segment of the latter, has also been insisted on by Miers and Brooks; this distinction is not, however, a real one. In the collection of the Natural History Museum at S. Kensington are several specimens with tumid carinae, with a median carina on the 6th abdominal segment, *but no sutures on the abdominal terga*; these specimens, having been originally labelled *G. graphurus*, have since been re-labelled, and I think rightly, by Dr Hansen as *G. glabrous*. It might be urged that there is no reason to regard the abdominal sutures as a more constant character than the median carina of the 6th abdominal segment; but I have seen examples of undoubted *G. glabrous* in the Natural History Museum (*i.e.* forms with sharply defined carinae) bearing a median carina, or traces of this carina, while Henderson also (*l. c. supra*) remarks "in *G. glaber* this carina is *usually* absent, *or at most but faintly indicated*" (italics mine); whereas I have never found *G. glabrous* showing any signs of the abdominal sutures of *G. graphurus*, though indeed I examined a fairly large number in the Natural History Museum in order to determine whether this character of *G. graphurus* would present transitional stages between itself and the smooth abdomen of *G. glabrous*. I have failed to find any such transitions, and should any other carcinologist consider this single character of sufficient value to separate *G. graphurus*

specifically from *G. glabrous*, this must be a question of interpretation in which we must agree to differ; though, should he agree with me in considering *G. glabrous* as a variety only of *G. chiragra*, I think it would be difficult to consider *G. graphurus* as anything but a variety of the same species, standing a step beyond *G. chiragra* var. *glabrous* in its relation to *G. chiragra* proper.

A further point in which var. *glabrous*, var. *mutatus*, and var. *graphurus* differ from *G. chiragra* is the greater elevation of the carinae, and the presence of two tubercles just beyond the distal end of the median carina, which seem to be correlated; an examination of figures 6—9 and 10—11 will show the stages leading up to this, the carina first becoming raised on a prominence of their own, and the posterior border of that prominence eventually breaking forth into two tubercles in var. *glabrous*. I also give figures of two *glabrous* forms (figs. 8—9) to illustrate some varying appearances of the three median carinae, showing actual connection, or signs of connection, between the submedians and medians: and here I would suggest that, from the point of view of consistency in the nomenclature of the carinae, the carinae on each side of the median carina in *G. chiragra* proper should be called the *lateral* carinae, corresponding to the external, or *lateral*, of the five carinae in var. *glabrous* and var. *graphurus*, reserving the term *submedians* for the intermediate carinae in these latter varieties.

Second heading. I. Var. *incipiens* a, var. nov. Pl. XXIII. fig. 10.

In this the carinae are tumid as in var. *tumidus* and without spines, but the median carina shows the first signs of the 'anchor' in the fact that, at its distal end, the sides are slightly grooved and a small portion separated off; the lateral marginal teeth are also present, but of small size only.

This is represented by a female, length 16·5, in the collection of the Cambridge Museum from Funafuti, Ellice Is., and is one out of some specimens referred to *G. chiragra* by Mr Borradaile. I am permitted to figure this form by the courtesy of Dr S. F. Harmer, F.R.S.

II. Var. *incipiens* b. Pl. XXIII. fig. 11.

The carinae are swollen; the median with a well-developed anchor, but no spine; the lateral marginal teeth well-developed.

This is the form chosen by Dr de Man as the type of the species, and figured by him in *Zool. Jahrb. Syst.* x. Pl. XXXVIII. Fig. 77, and the same as the forms referred to var. A (type) by Mr Borradaile in Willey's *Zool. Results*, Pt. IV. It is not represented in this collection.

III. Var. *segregatus* c. Pl. XXIII. fig. 12.

Forms the same as var. *segregatus* a, described on p. 92, but without a spine at the distal end of the median carina.

Not represented in this collection; but, as stated above, I have seen specimens from the Macclesfield Bank up to 30 mm. in length, and others from Kelantan and Penang in the Malay Peninsula up to 28 mm.

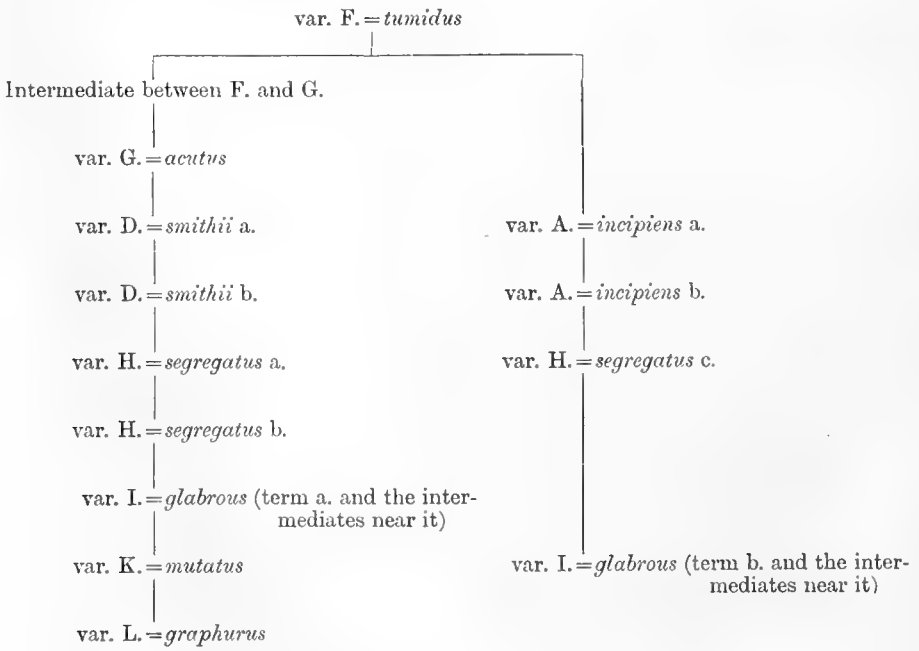
IV. Var. *glabrous* pars.

Carinae swollen, without any spines, or at best but tubercular rudiments of them.

This includes term *b* of this variety, and a certain number of the intermediates which approach very closely to it, the carinae being a little less swollen in varying degrees, and the spines generally absent.

The forms described above may be arranged, as I have said before, in a transitional scheme in such a way that, if we start, for convenience, from the *tumidus*-form, the rest of the forms come to lie along two closely parallel lines (corresponding to the two headings under which I have dealt with them), each of which may take the *tumidus*-form as its starting-point. This arrangement is shown in the following table, and I have affixed letter-symbols to each variety, in addition to the name-symbols, following on the line taken by Mr Borradaile in Willey's *Zoological Results*, Pt. IV. where five varieties are described and lettered from A to E; the first of my varieties, therefore, begins at F, while any varieties referred to by the letters A—E are the same as those correspondingly lettered by Mr Borradaile. The first column in the table forms a very perfect transition-series, but it must not be supposed that the transitions are exactly of the same degree as between form and form; thus, though I have separated var. D into two parts for the purposes of this transition-scheme, I should, had I been dealing with them by themselves, have treated them as one variety; this fact is expressed by giving them the same varietal name. The distinction between var. G and var. D is however definite, they are separated by a greater interval than the two parts of var. D, and this fact is expressed in the difference of varietal name. A similar situation arises in respect of the varieties in the second column in their relation to those of the first column; thus var. H in column 2, can scarcely be separated, on structural grounds, from var. H in column 1, whereas the two forms of var. A in column 2, though their structure requires them to occupy a similar position in column 2 to that which the two forms of var. D occupy in column 1, are still so far distinct from the latter varieties as to require a different varietal name.

This table then I arrange as follows:—



It may not be amiss to consider the facts brought out by an examination of these varieties in their relation to some theoretical considerations brought forward by Mr Borradaile in an earlier part of this work (Vol. I. Pt. II. pp. 193—198 "Marine Crustaceans. I. On Varieties").

1. It will have been noticed that, in cases where there is a sufficient number of any given variety, the individuals representing this variety come, not from one definite locality, but from different localities, a fact which bears out Mr Borradaile's statement, on p. 195, that "*there is no evidence of isolation* such as is presupposed in the evolution of two or more varieties simultaneously from a single species."

2. The transition-scheme which I have given of the *tumidus-glabrous* series has been arranged in two columns, arising out of the fact that two distinct lines of variation are present in the series, one being due to the development of the anchor leading to the formation of the submedian carinae, which is common to both the columns, the other being due to the presence or absence of a spine to the median and submedian carinae, such spines being present in first column (excepting var. *acutus* and *smithii* a.) and absent in the second. Now if the relation of these spines to the carinae be examined, it will be found that, according as the carinae are more tumid, the spines are less prominent; thus, taking extreme instances, it is seen that in var. *smithii* the median carina is almost sharp and has a strong spine, but that in the analogous var. *incipiens* the carina is very tumid and without a spine. Moreover, when, in var. *glabrous*, the carinae become more tumid, so as to produce eventually what I have called above "term *b*," the spines entirely or nearly disappear (var. *mutatus*, however, appears as an exception to this rule), as also do the carinae and spines on the 6th abdominal segment. Thus we find that the shape of the carinae and the development of the spines can only be taken as constituting a single differentiating character, the two apparent variations being, as Mr Borradaile has expressed it, in his footnote 2, to page 197, "coincident." A similar fact has been already brought forward by myself in dealing with some Malaysian Crustacea (*Ann. Mag. Nat. Hist.* (7) VI. 1900), where in dealing with *Actaea pulchella* var. *modesta* (p. 251) I have said, "It is true that three distinctions are noticed, but these three are really only one variation, the curvature of the dactyl and the gape of the fingers being implied by the emargination of the finger-tips." I give this case as another illustration of the point under consideration, and as helping to confirm, together with the present instance of *G. chiragra*, the more theoretical opinions expressed so clearly by Mr Borradaile in his footnote 2, p. 197; with which, I need hardly say, I find myself in entire agreement.

3. In dealing with var. *glabrous*, it has been seen that great difficulty existed in separating the intermediates between the two "terms" into definite groups, and I have above also expressed my reasons for believing that we have in var. *glabrous* a Continuous Variation series; the series being obtained, not from one, but from more than one locality. Now this fact conflicts to a certain extent with some remarks made by Mr Borradaile on pp. 196—7 to the effect that, where "well-characterised non-local varieties" exist, these varieties "are sundered by well-marked gaps"; and the writer adds, "In sorting fifty specimens of two varieties, there would not, in my experience, be more than two or three whose position would be doubtful" (see also footnote 1, p. 197). Now I do not deny the validity of Mr Borradaile's particular facts, which are, of course, cases of Discontinuous Variation, but his remarks seem to imply that, in *all* cases where we find well-characterised, non-local varieties, the variation will be

found to be Discontinuous, which I would modify by saying that in *some* (probably *most*) cases of this kind, the variation will be found to be of a nature of the above kind, but that in others it may be Continuous. This fact is of some importance. For, though the number of specimens before us is comparatively small, and though certainty of the presence of Continuous Variations must depend primarily on the examination of a very large series of specimens, yet the evidence before me hardly lets me doubt that, in such a character, for example, as the relative definition of the carinae, we are dealing with a Continuous Variation. Structurally the different degrees of this variation lead insensibly into one another and, statistically, it is not possible to separate the series into two groups, right and left, and say, "Here end the sharply-carinate, here begin the swollen"; the proportion of intermediates is too large for this, their number being greater than that of the two extremes. And, while making due allowance for the deficiency of the evidence owing to the relatively small number of specimens, I cannot but feel that we have here a Continuous Variation either presenting itself along with other Discontinuous Variations or, as in some cases, appearing without them. Now I have drawn attention above to the fairly close correlation between the definition of the carinae and the strength of the spines, the latter variation showing evident signs of discontinuity, so that we arrive finally at the idea of the coincidence, not only of Discontinuous Variations, as suggested by Borradaile, but also of Discontinuous and Continuous (Specific and Normal in Bateson's later phraseology) Variations. As far as the present instance informs us, it appears that, within the species, the Discontinuous is always coincident with the Continuous Variation (*e.g.* var. *smithii* and var. *segregatus* a) while the Continuous may appear without the Discontinuous (*e.g.* var. *acutus*); from the nature of the case this is only what might have been expected.

Third heading. Certain of the varieties of *G. chiragra* do not fall within the transitional scheme given above, nor can I relate them, with any preciseness, to any particular form among those I have described; they are the following:

I. Var. B. of Borradaile = *anancyrus*, Borradaile.

In the tumidity of the carinae and absence of 'anchor' this form resembles var. *tumidus*, but differs from it very notably in the presence of (1) well-developed lateral marginal teeth, and (2) a small tubercular spine on the distal end of the median carina.

II. Var. C. of Borradaile = *acutirostris* de Man.

Carinae not much swollen, without anchor, lateral marginals developed, carinae on submedian teeth converging forwards, angles of rostrum sharp.

I am a little dubious as to the value of the convergence of the carinae on the submedian teeth as a distinctive character: I have never seen this appearance in the numerous examples of the other varieties of *G. chiragra*, which I have examined both here and in the Natural History Museum at S. Kensington, and, as Dr de Man was dealing with a single specimen, it is possible that this very unusual feature represents an individual abnormality. The other characters are, no doubt, distinctive.

III. Var. M. = *spinosus* Bigelow. Pl. XXIII. fig. 14.

The three carinae are exceedingly swollen so as to touch each other along their sides, the carinae of the submedian and intermediate teeth are also swollen, and all the surface of the telson, except the bottom of the grooves, is covered with minute spinules. In one

specimen, however, in this collection, namely the largest, the surfaces of the three carinae are nearly smooth; with only a few scattered spinules. The intermediate marginal teeth are much reduced and the lateral marginals obsolete; the carinae of the 6th abdominal segment are considerably swollen, with or without terminal spines.

1 ♂, length 15, 1 ♀, 13, and three very small specimens, Hulule, Male Atoll; and 1 ♀, length 9, Goidu, Goifurfehendu Atoll.

IV. Var. N. = *espinosus* Borradaile.

Approaches nearest to var. *tumidus*, the three carinae being swollen as in that variety, but considerably less so than in var. *spinosus*; it resembles the latter in having the intermediate marginal teeth much reduced and the lateral marginals obsolete. The carinae of the submedian and intermediate teeth are sharply defined: the carinae of the 6th abdominal segment somewhat swollen, only the laterals with spines.

V. Var. O. Pl. XXIII. fig. 13.

Resembles var. *incipiens* a, but has an extra low carina on the median side of the intermediate marginal teeth. East-American.

I have seen, of this variety, one dry specimen in the S. Kensington Museum, and two spirit specimens in the Cambridge Museum; and am permitted to figure one of the latter by the kindness of Dr S. F. Harmer, F.R.S. In this figure it should be noticed that the median carina ends in an 'anchor,' a little more complete, perhaps, than in var. *incipiens* a but less complete than in var. *incipiens* b (compare figs. 10—11 with fig. 13, and these with Dr de Man's Fig. 77). In the brief note in which Dr Hansen describes his *G. oerstedii*, he lays stress only on the point in which his species *differs* from *G. chiragra*, namely the extra carinae on the intermediate marginal teeth, so that he naturally does not state whether the 'anchor' is present or not. As this 'anchor' may or may not be present in the eastern varieties of *G. chiragra*, it no doubt might or might not be present in Hansen's western form. Should Dr Hansen's original specimens be without the 'anchor,' then the name 'var. *oerstedii*' must be applied to the anchorless forms, and these anchored forms must be given a different name; but until this fact is definitely ascertained, I prefer not to name the present form, but to letter it only, for I think it very likely that Dr Hansen's forms will be found to present traces of the 'anchor.' These traces may vary considerably in the degree of their development, just as they do in var. *incipiens*, and in fact, in the second of the two Cambridge specimens, though it is of the same size as the first, the 'anchor' is so imperfect that its presence might be easily overlooked. (The two specimens are of different sexes, but I have seen no evidence of sexual variation in this character in the analogous var. *incipiens* or var. *smithii*.) Moreover, in the specimen from South Kensington, the anchor shows signs of separation from the median carina, though not to the same degree as in var. *segregatus*; the flukes, though quite separated from the median carina, are only imperfectly separated from each other in the middle line. The median carina, in this case, ends in a minute spine. In any case, the presence of the 'anchor' here is interesting as showing the very close affinities of the eastern and western forms, and if the western also varies, like the eastern, in regard to the presence or absence of the anchor, the evidence of relationship is still stronger.

VI. Var. O.? = *oerstedii* Hansen.

Similar to var. O. but ? without any anchor to the median carina. East-American.

VII. Var. P. = *festae*. Nobili.

Like var. *oerstedii*, but with spinules on the surface of the telson. West-American.

Of these six (or seven?) varieties, which I have grouped under heading three, the first two, namely var. *anancyrus* and var. *acutirostris*, differ so slightly in structure from *G. chiragra* var. *tumidus* that it would be impossible to consider them as anything but varieties, and as such they are estimated by Borradaile and de Man[1]. The other four present structural differences of somewhat greater magnitude, and have been considered by their authors as distinct species. I differ from these authors on the ground of later knowledge derived from the study of the *tumidus-glabrous* transition-series, which shows (1) that the species as such is highly variable and (2) that even structural differences as great as that between var. *tumidus* and var. *glabrous* are connected by intermediates. In the case of var. *spinosus* and var. *espinosus* we have no evidence of geographical isolation, the former being found both at Mauritius and in the Maldives, the latter being founded on a single specimen only from Rotuma; in the case of var. *oerstedii* and var. *festae* the evidence so far is in favour of such isolation, and we may therefore conclude, for the present, that we are dealing in these cases with distinct sub-species.

KEY TO THE VARIETIES OF *GONODACTYLUS CHIRAGRA*.

Carinae sharp.
- 3 carinae, well-defined.
  - No definite spine on middle carina; no anchor.
    - Rostral angles blunt; carinae on submedian teeth not converging..... *acutus*
    - Rostral angles sharp; carinae on submedian teeth converging ..... *acutirostris*
  - A definite spine on middle carina; anchor present ..... *smithii*
- 5 carinae, of which the submedian are more or less developed.
  - Submedian carinae well-developed with spines ..... *glabrous* (pars)
  - Submedian carinae ill-developed, with or without spines ..... *segregatus*

Carinae blunt, swollen.
- 3 carinae.
  - Telson spinous.
    - An extra carina alongside carina on submedian teeth ..... *festae*
    - No extra carina ..... *spinosus*
  - Telson not spinous.
    - Carinae very swollen, so as almost to touch each other ..... *espinosus*
    - Carinae not very swollen, with definite interspaces.
      - An extra carina alongside carina on submedian teeth ..... *oerstedii*
      - No extra carina.
        - 6 marginal teeth, anchor present ..... *incipiens*
        - 6 marginal teeth, anchor absent ..... *anancyrus*
        - 4 marginal teeth, anchor absent ..... *tumidus*
- 5 carinae.
  - Sutures on the terga of the abdominal segments ..... *graphurus*
  - Sutures absent; spines on the 3 middle carinae ..... *mutatus*
  - Sutures absent; no spines on the carinae ..... *glabrous* (pars)

[1] Var. *acutirostris*, however, differs in a much greater degree than does var. *anancyrus* if the convergence of the carinae on the submedian marginal teeth be taken as a constant character; a character which is so unusual in the species that I have preferred to regard it as a possible abnormality.

2. *Pseudo-squilla ciliata.* Miers.

Miers, *Ann. Mag. Nat. Hist.* (5) v. p. 108, Pl. III. Figs. 7—8 (1880).

♀, Minikoi, "Obtained by breaking up a coral mass from the outer reef," and a young form, Suvadiva Atoll, 30 *f.* (fathoms).

In the young specimen the submedian carinae on the telson, which are small in the adult, are quite absent. In describing the thoracic segments Miers says, "2nd thoracic segment...laterally sub-truncated, 3rd more rounded laterally." I think there must be a slip here on Miers' part, the arrangement in these specimens being just the reverse.

II. LARVAL FORMS.

3. *Alima bidens* Claus.

Claus, *Abh. d. kön. Ges. Wiss. Göttingen,* p. 152, Pl. VIII. Fig. 34 (1872); Brooks, 'Challenger' *Stomatopoda,* p. 90, Pl. IX. Figs. 1—2 (1886).

A single example from Suvadiva Atoll, Maldive Is., 30 *f.*

In this specimen, which is 25·5 mm. long and therefore of the same size as the older of Brooks' two specimens, the three teeth (besides the terminal one) on the dactyl of the raptorial claw are represented by only the merest rudiments under the skin, and there is only one spine on the inner edge of the postero-lateral spine, as opposed to three in Claus', and two in Brooks' specimens; the spines on the postero-lateral angles of the abdominal segments are, however, well-developed.

4. *Alimerichthus pyramidalis* sp. n.

Cp. Claus, *Alimerichthus,* sp. *Abh. d. kön. Ges. Wiss. Göttingen,* p. 147, Pl. VIII. Fig. 30 (1872); and Brooks, 'Challenger' *Stomatopoda,* p. 97 (1886).

Of this species there is one example in the collection. This, which is from the North Male Atoll, is 17 mm. in length and thus corresponds in size with Claus' example, with which, moreover, it corresponds closely in other structural details; there are, however, indications of only 5 (or possibly 6) spines on the dactyl of the raptorial claw, and 5 spines only on the exopodite of the uropod. As points which have not been described before, I may mention that all the abdominal segments bear spines on their postero-lateral angles, while the 6th abdominal segment bears a pair of submedian spines. Also the dorsal spine rises from a pyramidal elevation of the carapace, the angles of which pyramid form carinae, not sharp but rounded, which are continued, one along the mid-dorsum to the rostrum, the other two along the posterior border of the carapace to the postero-lateral spines, the posterior border being bent downwards behind these two carinae.

Claus makes no mention, in his description of this species, of spines on the postero-lateral angles of the abdominal segments, and the point cannot be decided from his figure. Brooks, however, says on p. 98 of his work, "In the true *Alimae* the postero-lateral angles of the abdominal somites end in acute spines, which are not developed in *Alimerichthus.*" This I believe to be an error; firstly, because inspection of his figure 3 on Pl. IX. reveals the presence of such spines on at least the 3rd—5th segments; secondly, because the present specimen, which has such spines, agrees so closely with the one dealt with by Claus as to

make it more than probable that, in the absence of definite evidence to the contrary in Claus' work, his specimen was armed with these spines; and thirdly, because similar spines are present in the other example of an *Alimerichthus* described below.

Loc. North Male Atoll, Maldives, 27—35 f.

5. *Alimerichthus unidens* sp. nov.

A single example from South Nilandu Atoll, 19—25 *f.*

This species agrees in so many points with the preceding that, on a first examination, I was inclined to consider them as identical. The carapace has the same arrangement of primary and secondary spines, and a similar pyramidal support for the dorsal spine; the abdomen has spines on the postero-lateral angles, and submedians on the 6th segment; the uropods and telson are exactly similar. Two conspicuous differences mark the species off very clearly. Firstly, its size; the greatest length of the animal being only 12·5 mm., it is obvious that, were it specifically identical with *Alimer. pyramidalis*, it should represent an earlier stage in the development of that species, a stage in which the uropods should be but little developed and the telson wider in proportion to its length, as is the case even in a specimen 15·5 mm. long figured by Brooks (*l.c.* Pl. IX. Fig. 3); seeing, however, that it is in the same stage, structurally, as the 17 mm. larva described, and as the 16—18 mm. larva of Claus, it is extremely unlikely that we are dealing here with that species; rather we must believe that we have a different larval species in which the structural advances correspond to a smaller advance in size than in *Alimer. pyramidalis*. This view is strengthened by the second difference to be noted, namely, that the dactyl of the raptorial claw is armed with one *fully-developed* spine in addition to the terminal one, and possesses rudiments, proximally to this, of only two others; pointing to its connection with an adult species of *Squilla* in which there are fewer spines on the dactyl than in the adult of *Alimer. pyramidalis*.

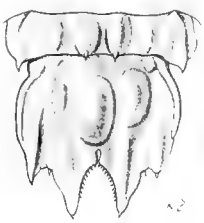
6. *Coronideriehthus bituberculatus* Hansen.

Isopoden, Cumaceen, u. Stomatopoden der Plankton Expedition, p. 83 (1895). *Erichthus armatus* Claus (pars), *Abh. d. kön. Ges. Wiss. Göttingen*, XVI. Pl. IV. Figs. 15—15[1] (1872).

One specimen from Suvadiva Atoll, Maldive Is. 44 *f.*, which accords closely with Claus' figures. There is a secondary tooth between the submedians and sublaterals of Hansen, representing his intermediate; in addition, and these are not figured by Claus, are two small spines, one at the base of the sublaterals, the other at the base of the laterals. There are three rudimentary teeth under the skin on the dactyl of the raptorial claw, and two submedian spines on the 6th abdominal segment.

[NOTE. When this paper was written I had not seen the description of two varieties by Dr de Man in a recent paper, "Die von Herrn Prof. Kükenthal...gesam. Dekap. u. Stomatopoden," 1902. Dr de Man's var. *affinis* is coextensive with my var. *segregatus*, his name having priority, but presents certain differences: similarly his var. *confinis* seems to be coextensive with var. *anancyrus*, though again presenting differences. The reader should refer to p. 912 of the above-cited work. Dr de Man agrees with me in considering var. *affinis* as transitional to var. *glabrous*.]

1.



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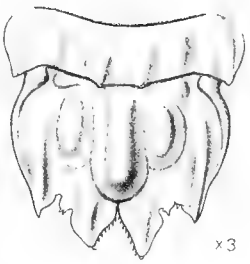

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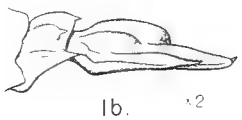
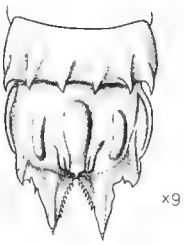


1b.

3a.

4.

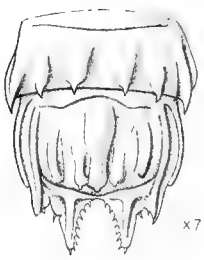
5.



6.

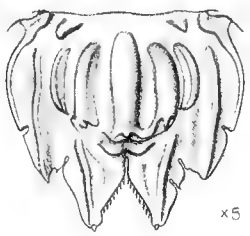
4a.

7a.



7.

8.



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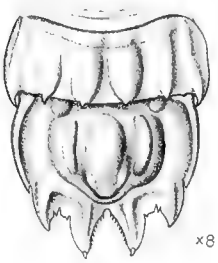


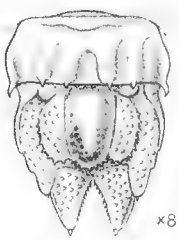
10.

15.

11.

12.

13.



14.

E Wilson Cambridge

EXPLANATION OF PLATE XXIII.

The telson and 6th abdominal segment of some of the varieties of *Gonodactylus chiragra*.

FIG. 1. Var. *tumidus*, type. 1 *a*. An individual showing traces of the lateral marginal teeth. 1 *b*. Lateral view of the type.

FIG. 2. Form connecting var. *tumidus* with var. *acutus*.

FIG. 3. Var. *acutus*. 3 *a*. Lateral view of the same.

FIG. 4. Var. *smithii* a. 4 *a*. Lateral view of the same.

FIG. 5. Var. *smithii* b.

FIG. 6. Var. *segregatus* a.

FIG. 7. Var. *segregatus* b. 7 *a*. Lateral view of the same.

FIGS. 8, 9. Var. *glabrous*. Forms showing connection, or signs of connection, between median and submedian carinae.

FIG. 10. Var. *incipiens* a.

FIG. 11. Var. *incipiens* b.

FIG. 12. Var. *segregatus* c.

FIG. 13. Var. O = *oërstedii*?

FIG. 14. Var. *spinosus*.

FIG. 15. Var. *glabrous*, term b.

THE LITHOTHAMNIA OF THE MALDIVES AND LACCADIVES.

By M. Foslie, *in Trondhjem.*

(With Plates XXIV and XXV.)

The Lithothamnia of the tropics have been rather disregarded. Although for a long time known as appearing in a great number of individuals, up to late years only a few species of rather uncertain limits have been distinguished. This applies to the branching as well as crust-like forms. The latter and in part the branching also have often been considered to represent a solitary and supposed cosmopolitan species, *Phymatolithon polymorphum* (*Lithothamnion polymorphum* auct.), while in reality this plant shows a rather restricted geographical distribution, being properly known to occur only in some parts of the North Atlantic and within the southern part of the Arctic Sea. In regard to species also the Lithothamnia have now been shown to be richly represented in the tropics, as of late years rather numerous species have been described. Little, however, is as yet known with regard to their geographical and vertical distributions. Therefore, every contribution may help to extend our knowledge of these plants, which appear to be significant and interesting in several respects.

Till now not a single species with certainty has been recorded from the great area between the Red Sea and the East Indies. Mr Stanley Gardiner, however, collected a number of Lithothamnia during his expedition to the Maldives and Laccadives in 1899—1900. He has done me the favour of submitting this collection to my research. It is interesting, especially as regards the geographical distribution of several species, and at the same time tends to show what forms chiefly act together with corals as reef-builders.

The calcareous algae in question, in the northern temperate zone as well as in the Arctic Sea, occur rather independently and, as a rule, form greater or smaller banks in the sublittoral zone down to a depth of about 20 fathoms[1]. In the tropics these algae partly seem to be confined to coral-reefs, and partly form independent banks, which mainly consist of calcareous algae freely, or apparently freely, developed on the bottom. The growth of the species under different conditions, however, is still but little observed, as well as to what extent banks, or masses, of these algae occurring on reefs consist of one or more species. I may mention that banks in the tropics seem not unfrequently to be composed of a single species, as is very often the case in the temperate zone. Thus the Challenger expedition

[1] F. R. Kjellman, "The Algae of the Arctic Sea." Stockholm, 1883. M. Foslie, "The Norwegian Forms of Lithothamnion." Trondhjem, 1895.

met with a bank off Tahiti, which had probably been formed by a single species, *Lithothamnion Dickiei*[1]. In *Suppl. Alg. Tahiti*[2] the following note is added:—"A calcareous alga in rounded masses forming the bottom in 10 fathoms off Great Island (Santa Cruz Major), Zambonga. The dredge came up filled with these masses." The Dutch Siboga expedition has pointed out several banks in the Malayan Archipelago, which apparently consist of only one species or have one especially predominating[3]. A peculiar occurrence of large quantities of a Lithothamnion has been mentioned by Madame A. Weber—van Bosse from the above expedition off Haingsisi on the Samau Island near Timor. Here *Lithothamnion erubescens* f. *haingsisiana* in the littoral zone forms a bank which becomes dry at low tide. It is indeed well-known that Lithothamnia occur between tide marks, and that certain forms even chiefly are to be found there; for instance some forms live in shady localities or in rock-pools, which are filled with water at the ebb, yet none grow in large quantities except in the lowest part of the zone and are then for a short time only more or less dry. In such parts as are completely dry for several hours, at any rate in the northern temperate zone and within the Arctic circle, are generally found only crust-like species. Branching forms are seldom met with even in the lower part of the littoral zone, and almost only such as at the same time form a rather strong crust. But in the above places *Lithothamnion erubescens* occurs—forming rather large nodules, which are richly, but densely branched—in such masses that the plant makes its mark in the vegetation, or forms a real bank (*Vide l.c.* Pl. XVIII—XIX). Nothing like this appears to have been met with before.

It seems as if some Lithothamnia do not thrive in connection with certain corals or especially certain Polyzoa, but on the other hand, as remarked above, other species appear to be rather confined to coral-reefs. These algae in general are apparently not dependent on physical or chemical conditions, apart from requiring, like other algae, at least a fairly hard bottom, and besides as a rule a partly exposed habitat over which the tides are running more or less rapidly. But some species, which frequently stick to stones or shells of mollusks, show a tendency in some degree to modify their structure when attached to certain corals or coarse Polyzoa, while the same species growing on other corals or Polyzoa do not differ from their typical development. This is due to the hypothallic or basal layer of the plant and of course owes its origin in the main only to the size of the cells and the mutual proportions between the hypothallic and perithallic layers of tissue. Moreover, such species which form real and independent banks at the bottom seldom or never appear to occur in coral-reef areas. Other species on the contrary seem to prefer corals as substrata or places where they abound. There are species known only from coral-reefs, or occurring on them in much larger numbers and more vigorously developed than in other places, but there are also species appearing equally distributed both on such reefs and in other places suitable for their development. It seems even to be a rule that species which principally appear on coral-reefs frequently are to be found in great masses, though properly speaking scarcely forming definite banks. These relations are as yet but little observed. It appears, however, to be worth a closer investigation whether the points suggested above depend on accidental circumstances or are of a more crucial significance.

[1] M. Foslie, "New or critical calcareous Algae." Trondhjem, 1900.

[2] Dickie, "Notes on algae collected by H. N. Moseley of H.M.S. 'Challenger,' chiefly obtained in Torres Straits, coasts of Japan, and Juan Fernandez." *Linn. Soc. Journ. Bot.*, Vol. xv. p. 452: 8. "Algae collected on the Reefs of Tahiti." 9. "Supplement to preceding collection."

[3] A. Weber—van Bosse, "Études sur les algues de l'Archipel Malaisien." *Annales du Jardin Botanique de Buitenzorg*, Ser. 2, Vol. II. p. 126. Leide, 1901.

Among the calcareous algae in question which only, or almost only, occur on coral-reefs and there play a prominent part as reef-builders, it seems as if the coarse *Lithophyllum craspedium* may be placed in the front rank. Thus this species is apparently the predominant alga in certain atolls of the Maldives (Pl. XXV. fig. 1). The same species also abounds at Funafuti, and at Onoatoa, Gilbert Islands, is a very abundant type. According to a label, "this Nullipore, Finckh says, is actually the reef-former at Onoatoa. He saw no live coral there, but everywhere on the lagoon and ocean-face immense masses of this particular Nullipore." Next to the last named species, *Goniolithon frutescens* appears to be abundant in the Maldives, and is there especially numerous on the sand-flat of Hulule, Male Atoll. This rather finely branching species also occurs at Minikoi Atoll in the Laccadives. Further it is common at Funafuti, where it was first met with, and the collector remarks that the species is very abundant off the leeward (W.) islets, but is also found in great numbers in other parts; he considers it to be a rather important reef-builder. A form of this species, represented by dead and fragmentary, apparently rather young specimens, also from Funafuti, has been indicated as an important rock-former; the specimens comprise especially the crustlike parts of the plants with short branches, but in contradistinction to other specimens are of a hard consistency. They in part remind one of calcareous sediment, and are anastomosed with fixed corals or fragments of corals. In addition, the crustlike *Lithophyllum oncodes* appears to act as a kind of cement, and is apparently abundant in the Maldives as well as at Funafuti and other places both in the Indian and Pacific Oceans. There are still a number of other species, which in greater or less degree contribute to the formation of reefs, and sometimes even form layers almost alternating with corals, Polyzoa, Foraminifera, etc. Their occurrence and significance are, however, too little known to me to be specially mentioned here.

It has been considered by some recent authors that algae having an incrustation of carbonate of lime occur much more plentifully in the warmer than in the temperate oceans; or, in other words, a very slight amount of carbonate of lime is supposed to be developed in the cold waters of the polar regions. According to our present knowledge of the distribution of the Lithothamnia in different zones, this view is not correct. On the contrary, numerous large banks of these algae are to be found in the Arctic as well as in the temperate zone, though the number of species is less in the former seas. Thus on the coast of Spitzbergen and Nowaya Zemlya *Lithothamnion glaciale* "covers the bottom in deep layers for several miles, and altogether determines the general aspect of the vegetation, wherever it occurs. In the formation of future strata of the earth's crust in this region it must become of essential importance[1]." It is also known that *Lithothamnion Ungeri* forms banks on the coast of Iceland, and also on the coast of Greenland. Indeed, these algae are common and plentiful, partly even occurring in masses[2]. North of the polar circle on the coast of Norway banks have been met with, which cover the bottom for several miles, and plants appear in immense masses frequently representing only one species. Farther to the south, for instance in the Trondhjem Fjord, rather large banks are to be found which may be composed of a solitary small species such as *Lithothamnion norvegicum*, or other and extensive banks of larger species which form deep layers built up in vertical direction, so that they in part may be almost laid dry at lowest springs. In the same locality subhemispherical specimens have been found, which vary up to half a metre in diameter, weighing nearly 6 kilogrammes in a dried state. Similar specimens are also found on the south-west

[1] F. R. Kjellman, "The Algae of the Arctic Sea." Stockholm, 1883, p. 96.

[2] Kolderup Rosenvinge, *Grönlands Havalger. Kjobenhavn*, 1893, p. 772.

coast of Norway. The banks in these positions are built up entirely of the algae in question, and as a rule each bank comprises only one species, but at the same time it serves as a shelter for a very great number of various animals, though not corals. In such banks is often to be seen an interesting struggle for existence between plants and animals. Further it may be remarked, that in several places along the Norwegian coast rather large quantities of dead Lithothamnia have been brought up by excavators in harbours, where living specimens are no more to be found. On the west coast of Ireland I have also seen great masses of partly dead, partly living, specimens. On the whole, smaller or larger banks appear almost everywhere at least in northern waters, in places where the nature of the bottom allows their existence and the tides are running rapidly.

In regard to the habitat of the Lithothamnia in the Maldives, Mr Stanley Gardiner kindly communicated to me some observations on the collection, of which I may quote the following. The names within parentheses are added by me as the supposed species in question.

"The finely branching species or specimens are all from the sand-flat (*Goniolithon frutescens*). Massive (not branching) forms are practically invariably from the outer, i.e. seaward face of the reef near the breakers. Specimens roughly resembling (*Lithothamnion fruticulosum* f. *crassiuscula* and *Lithophyllum Kaiserii*?) are almost invariably dredged either to seaward of the reef or in passages generally down to about 25 fathoms. Rounded nodules like marbles or eggs (*Lithophyllum Reinboldi*?) are invariably from deep passages into the lagoons of atolls or interiors of banks. They lie there together with similarly shaped masses of *Polytrema* and Polyzoa (each usually with a nucleus of dead coral). Presumably all these are rolled over and over with the currents.

"In the lagoons of Suvadiva, Addu and other closed atolls Lithothamnia were never dredged. Perhaps this was partially owing to the sandy or muddy bottom preventing their growth, but even close round shoals, where the bottom was covered with coral fragments, Lithothamnia were never found. In similar situations to the last in the open banks of Miladumadulu and N. Mahlos I have found small growths a square centimetre or so, but never obtained a separate large plant."

"In reference to the reefs, branching growths (*Goniolithon frutescens*) may be found more or less imbedded in the sand of the sand-flat in any situation where they are never uncovered and the water circulates freely. Thus to the E. of Hulule such growths were found, but not on the west or lagoon side. On the reef to the E. (seaward reef) the Lithothamnia presented their usual abundance, most plants being encrusting with smooth surface (*Lithophyllum oncodes* and *Goniolithon Fosliei*), some however coarsely mamillated (*Lithophyllum craspedium*). At the extreme edge under the breakers massive or incrusting growths covered the greater part of the rock on many reefs, and on the reef-flats behind a few plants were growing in hollows. On the W. reef (lagoon reef) of Hulule island no Lithothamnia were ever found except at the extreme edge. Here such growths as existed were very small and crowded out by corals. Several series of dredgings were taken off this reef in 10, 15, 20, 25 and 28 fathoms. The only Lithothamnia obtained were two small nodules between 25 and 30 fathoms almost off the end of the passage."

Genus **Archaeolithothamnion** (Rothpl.) Fosl.[1]

1. *A. Schmidtii* Fosl.

Corall. in Schmidt, *Fl. Koh Chang*, II. p. 16.

f. *dissita* Fosl. mscr. (Plate XXIV. fig. 1).

Branches rather scattered and up to 3 mm. thick, increasing in thickness upwards.

Only two specimens were till now known of the typical form of this species, and these so exactly resembled each other, that it is uncertain whether the species shows any tendency to variation. Notwithstanding this, I refer the above form to *A. Schmidtii*, although it rather differs in habit from the type of the latter. Thus even in an advanced stage the branches are not so crowded as in the typical form, but the crust itself is of about the same thickness. They frequently issue at intervals of 3—5 mm., nearly always increasing in thickness upwards, or occasionally with almost spherically thickened ends, and up to about 8 mm. long. In addition they are most often thicker than the average in the type, but on the other hand less knotty. In regard to structure and sporangia the plant in the main agrees with the typical form. There seems, therefore, to be reason, at least at present, not to consider f. *dissita* more than a form of *A. Schmidtii*.

The present form of the species appears to grow in somewhat sheltered places. It is, however, according to the label only known with certainty from the lagoon of Addu atoll (25 fathoms). About this atoll Mr Stanley Gardiner remarks: "Its reef is perfect except for two small passages to the north and two larger ones to the south. The lagoon has a maximum of depth of 32 fathoms; it is fairly open in the centre, but against the encircling reefs has a perfect maze of coral heads, arising from 7 to 10 fathoms." The plant was sterile when dredged in the middle of April, being however sparingly provided with overgrown cavities of sporangia.

Locality. The Maldives. Only one specimen with certainty known from the most southern part of the Maldive group, viz. Addu atoll. Another and a younger one is perhaps from Hulule, Male atoll, though possibly from some other atoll.

Genus **Lithothamnion** Phil. (Fosl. emend.).

2. *L. fruticulosum* (Kütz.) Fosl.

List of Lith. p. 6 (non Norw. Lith.); *Spongites fruticulosa* Kütz. *Polyp. Calcif.* p. 33 et *Tab. Phyc.* 19, t. 99. Syn. *L. fasciculatum* β. *fruticulosum* Hauck, *Meeresalg.* p. 274.

f. *clavulata* Fosl.

Corall. in Schmidt, *Fl. Koh Chang*, p. 17.

f. *crassiuscula* Fosl. (Plate XXIV. fig. 2).

Corall. in Schmidt, *Fl. Koh Chang*, p. 17.

Three small and rather delicate specimens of f. *clavulata* from two localities coincide with the specimens known from the Gulf of Siam. They also fully agree in habit and

[1] With regard to the limit of the genera I refer to "Revised Systematical Survey of the Melobesieae." Trondhjem, 1900.

structure with somewhat stunted growths from the Mediterranean and the Adriatic. The only difference appears to be, that the conceptacles of cystocarps are more acute than generally seen in specimens from the last-named regions. Therefore, there seems to be no reason to consider the alga from the Indian Ocean, hitherto only known from the Gulf of Siam and the Maldives, as a form so differing from the Mediterranean and Adriatic f. *clavulata*, that it ought to be specially denominated.

As remarked in a pamphlet in press[1] there is a considerable difference in habit between a delicate f. *clavulata* and a coarse f. *crassiuscula*, but I have been unable to draw any true limit between them. They are both pictured in the said pamphlet together with a still more delicate and rather curious form, which I have named f. *soluta*. A coarse specimen of f. *crassiuscula* is also to be found in the collection from the Maldives (Plate XXIV. fig. 2). It seems as if this form has a tendency to get a little coarser in the tropics than is generally the case in the Mediterranean or the Adriatic, as in the latter regions the greatest number of specimens show slightly thinner branches, although not seldom fully agreeing even in this respect. On the other hand the specimen from the Maldives fully coincides with the same form of the species known from the south coast of Australia, where it seems to be rather abundant. This form probably occurs also in other parts of the Indian as well as Pacific Ocean.

Besides the specimen of f. *crassiuscula* four other specimens were found in the present collection. These represent a form which is closely connected with f. *crassiuscula*, but differing in some respects (Plate XXIV. fig. 3). The specimen here pictured reminds one in habit of an old *Goniolithon Brassica-florida*, but, as mentioned in the above quoted pamphlet, in the Adriatic as well as in the Mediterranean these two species sometimes rather approach each other in that respect, though otherwise being quite different. These four Maldive specimens form nodules up to about 6 cm. in diameter, which look as if they had been freely developed at the bottom. They surround, at least in part, pieces of corals. Their consistency is more compact than in typical f. *crassiuscula*, the surface even a little shining, but, above all, their conceptacles of sporangia are somewhat smaller. The latter sometimes are about 600 μ in diameter seen from above, but in most cases only 400—500 μ. They are now and then slightly depressed in the central part, especially towards maturity, and their muciferous canals are somewhat crowded in the roof, as also occasionally occurs in typical specimens of the form.

In structure this Maldive form coincides in the main with typical *L. fruticulosum*. A section shows that the plant has been much attacked by lower animals, and numerous new formations have been built up over each other, in part almost alternating especially with Polyzoa. A consequence of this often seems to be, that the hypothallic layer gets more vigorously developed, or the cells larger and, especially, more elongated than would otherwise be the case. I have formerly shown that, for instance in *Lithothamnion Philippii*, the corresponding cells under similar conditions sometimes become even much larger than under a normal development. This seems especially to be the case when the plant sticks to certain Polyzoa, chiefly coarse and large-celled ones, while on the other hand certain corals seem to give rise to a rather feeble development of the basal layer of the plant. In several of the new formations in the specimens the hypothallic layer is vigorously developed, more or less coaxillate, and often composed of larger cells than generally observed in the species. The

[1] "Die Lithothamnien des Adriatischen Meeres und Marokkos." *Wissensch. Meeresuntersuchungen, Abt. Helgoland.*

cells of the perithallic layer vary greatly in size, as is often the case in calcareous algae burdened with animals. They coincide, however, in the main with the species in question.

Therefore, also these four specimens in my opinion must be referred to *L. fruticulosum*, and are so closely connected with f. *crassiuscula* that in fact they probably only represent an outer limit of this form. A solitary specimen from the most southern part of the Maldive group, Addu atoll, is perhaps referable to the same species. It seems to have been dead when picked up from a depth of about 40 fathoms, but as sterile and not typical it cannot be determined with certainty.

At the Maldives the species apparently occurs in the sublittoral zone and under much the same conditions as in most other places. It is not known with certainty from what depth this plant was dredged in Male atoll, but in S. Nilandu, "an atoll somewhat similar to Male," f. *clavulata* was obtained at 19 and 35 fathoms, thus rather deeper than for instance in the Gulf of Siam, where it was brought up from 9 fathoms. Indeed f. *clavulata* appears frequently to descend deeper than f. *crassiuscula*. Both forms are provided with reproductive organs in January, especially sporangia, while carpospores are scarce.

Locality. The Maldives: Hulule, Male atoll (f. *crassiuscula* and a small specimen of f. *clavulata*); S. Nilandu (f. *clavulata*); and Addu atoll (uncertain).

Genus **Lithophyllum** Phil. (Fosl. emend.).

3. *L. Reinboldi* A. Web. et Fosl. (Plate XXIV. fig. 4) in *Vidensk. Selsk. Skr.* 1901, no. 1.

In the collection there was a well-developed typical specimen of this species from the Laccadives, attached to an oyster-like shell, and another and quite young one, sticking to a piece of coral. A single specimen from the Maldives (Plate XXIV. fig. 4) bears a few young branches of *Goniolithon frutescens*, which shows that both species probably appear gregariously in the same habitat.

It seems as if this species partly grows in the lower part of the littoral zone, partly in the upper part of the sublittoral zone, but apparently not descending to any considerable depth. At the Laccadives the plant is furnished with sporangia towards the end of July, and at the Maldives in the latter half of April.

This species appears to be widely dispersed in the Indian Ocean. It has been known for a long time from Samoa and Zanzibar, but was not described until collected by Madame A. Weber—van Bosse on Moearas-reef, east coast of Borneo, and at Banda during the Siboga expedition. It is also known from the Tami islands, New Guinea (*L. cerebelloides* Heydr.), and the Hawaiian islands in the Pacific Ocean.

Locality. The Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll.

4. *L. craspedium* Fosl.

New or crit. calc. Alg. p. 26.

f. *compressa* Fosl. (Plate XXV. fig. 1).

Calc. Alg. Funafuti, p. 7.

f. *abbreviata* Fosl. (Plate XXV. fig. 2).

Calc. Alg. Funafuti, p. 7.

The specimen of f. *compressa*, pictured Plate XXV. fig. 1, does not represent the type of this form, the branches being somewhat broader and more compressed in typically developed specimens. On the other hand the branches sometimes may be almost terete, and it seems that this form in fact is the typical form of the species. So also with reference to f. *abbreviata*, the specimen, pictured Plate XXV. fig. 2, shows the transition to f. *subtilis*, a still more delicate form, although standing nearest to the former.

This vigorous alga appears to be an important reef-builder at several places in the Indian as well as Pacific Ocean, and is known from Funafuti and Onoatoa Gilbert Island. At the Maldives it seems to be abundant in certain localities, attaining a height of upwards of 10 cm. The plant frequently grows in company with other species, as *Goniolithon frutescens*, *G. Fosliei* and *Lithophyllum oncodes*, the last crustlike species sometimes even covering the lower part of *L. craspedium*. It seems to occur in the lower part of the littoral and upper part of the sublittoral zone, but scarcely descends deeper. The old specimens collected are sterile, as is frequently the case in this group of algae, while the younger ones bear more or less numerous sporangia in January.

Locality. The Maldives: Hulule, Male atoll.

5. *L. Kaiserii* Heydr.

Lithothamnion Kaiserii Heydr. in *Ber. Deutsch. Bot. Ges.* 1897, p. 64.

Lithophyllum Kaiserii Heydr. *l.c.* p. 412.

f. *typica.*

L. Kaiserii Heydr. *l.c.*

f. *subplicata* Fosl.

In *Videnskr. Selsk. Skr. Aarsber.* for 1900, p. 14.

As formerly remarked, it seems doubtful to me whether this plant may be considered a separate species, or in fact is only a form of *Lithophyllum racemus*. I have previously classed it with the latter. It has been up to the present found only in the Red Sea and some places in the Indian Ocean, while typically developed specimens of *Lithophyllum racemus* are only known from the Mediterranean and the Adriatic. The latter plant is somewhat varying, and several forms from other regions are recorded which as to habit cannot possibly, or only with difficulty, be separated from it. This at least in part also applies to *L. Kaiserii*, which sometimes almost fully resembles certain forms of *L. racemus*, sometimes rather differs. With reference to structure, the cells on a longitudinal section of a branch often are a little longer and more narrow. But not even in this respect is any true limit to be drawn, as also *L. racemus* often shows at least in part the same structure. However, I consider the species in question a separate one, until it as well as other nearly allied species may have been more fully examined in a larger amount of material from different localities. Among these species are especially *Lithophyllum Okamurai* Fosl. (including *L. cephaloides* Heydr.), *L. pallescens* Fosl. and *L. fasciculatum* (Lam.) Fosl.

At the Maldives *L. Kaiserii* seems to be rather abundant, partly appearing in its typical form, partly rather differing. An almost typical specimen is pictured in Plate XXIV. fig. 7. Sometimes the plant becomes coarser and less densely branched, as the specimen represented in Pl. XXIV. fig. 5. Sometimes it more or less agrees with f. *subplicata*. A coarse specimen of the latter form with rather broad branches is represented in Pl. XXIV. fig. 6. This form

sometimes approaches *Lithophyllum congestum* in habit, or even reminds one of *L. platyphyllum*, while as remarked above the species in fact is most closely related to *L. racemus* and *L. Okamurai*.

This species seems to occur in the sublittoral zone, but it is unknown to what depth it descends. It is most frequently attached to corals, from which, however, it seems sometimes to loosen itself, or is freely developed at the bottom. The plant is sparingly provided with reproductive organs in January.

Locality. The Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll, quite young and not certain.

6. *L. oncodes* Heydr.

Lithothamnion oncodes Heydr. in *Bibl. Bot.* 41, p. 6; and *Ber. Deutsch. Bot. Ges.* 1897, p. 410.

The species forms more or less thick and rather smooth crusts on rocks or corals. At the Maldives as well as the Laccadives it appears partly in its typical, partly in a somewhat varying form. The latter shows a rather uneven surface, which in the main depends on the shape of the substratum, and in addition slightly differs in structure. On a cross section the cells are here and there larger than is generally found, more regular, and with their longest diameter in a vertical direction. These differences seem to me not to be of such importance that they justify one in supposing it a separate species or form.

The plant always appears to occur in the lower part of the littoral and uppermost part of the sublittoral zone, scarcely descending deeper. It often grows in company with other species, as *Lithophyllum craspedium* and *Goniolithon frutescens*, and seems in some places to be a rather important reef-builder. Specimens collected in the Maldives in January and in the Laccadives towards the end of July are partly furnished with reproductive organs.

Locality: the Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll.

Genus **Goniolithon** Fosl.

7. *G. frutescens* Fosl.

Calc. Alg. Funafuti, p. 9.

f. *typica* (Plate XXV. fig. 4).

f. *congesta* Fosl. mscr. (Plate XXV. fig. 5).

Branches densely crowded and fastigiate.

In the typical form, as well as in f. *flabelliformis*, the branches are rather irregular in height and most often not densely crowded, reminding one in habit of the similar forms of *Lithophyllum moluccense*. In f. *congesta* on the other hand the plant forms hemispheric or roundish balls up to 6—7 cm. in diameter, with densely crowded and on the whole strongly fastigiate branches (Plate XXV. fig. 5). Besides, the branches frequently are thinner than in the other forms, seldom more than 2 mm. thick. This form is very characteristic in its typical shape, showing however numerous transitions to f. *typica*, although even in a young state the branches are a little thinner, with proportionally shorter axes than in the latter. Plate XXV. fig. 6 shows a young specimen of an intermediate form, which however comes nearest to f. *congesta*. Typical specimens of f. *flabelliformis* are not to be found in the

present collection, but on the other hand rather numerous and well-developed specimens of f. *typica*.

This species appears to be widely dispersed in the Indian, as well as a part of the Pacific Ocean. Together with *Lithophyllum craspedium* and *L. oncodes* it seems to be the most abundant calcareous alga of the Maldives, and apparently is also rather common in the Laccadives. The plant probably occurs gregariously, especially in the lowest part of the littoral zone and upper part of the sublittoral, and is partly attached to corals or rocks, partly either freely developed at the bottom or imbedded in the sand of the sand-flats. It also seems often to loosen itself from the substratum and to continue its growth in the free state. The specimens are provided with reproductive organs in January, although rather sparingly.

Locality. The Maldives: Hulule, Male atoll, and Suvadiva atoll; and the Laccadives: Minikoi atoll.

8. *G. Brassica-florida* (Harv.) Fosl.

List of Lith. p. 9; *Melobesia Brassica-florida, Harv. Ner. Austr.*, p. 111.

f. *laccadivica* Fosl. mscr. (Plate XXV. fig. 7).

Thallus forming crusts on corals 0·5—1·5 mm. thick, with simple or sparingly divided short branches, 2—2·5 mm. thick. Conceptacles of sporangia conical, 800—900 μ in diameter when seen from above.

The present plant surrounds a branch of a coral, the latter towards 1 cm. thick, and forms a crust 0·5—1·5 mm. thick. From this crust issue crowded in part somewhat anastomosing branches which are simple or sparingly divided, frequently 3—7 mm. long and 2—2·5 mm. thick, with rounded ends. The branches are now and then knotty.

The hypothallic layer is well-developed, coaxillate, and the cells frequently 15—25 or up to 30 μ long and 9—12 μ broad. The perithallic layer forms more or less distinctly stratified layers of tissue, partly with rounded cells 9—12 μ in diameter, partly and most frequently with vertically elongated, 12—18 μ long and 9—12 μ or occasionally 15 μ broad. Here and there appear rows of larger cells. Heterocysts are not numerous.

The conceptacles of sporangia are to be found somewhat scattered in the branches. They are conical, a little contracted in the middle part, but their more or less elongated upper part falls away at maturity. They are 800—900 μ in diameter, seen from above, and the sporangia are four-parted, 120—160 μ long and 45—55 μ broad.

I have been uncertain whether this plant ought to be considered a form of the above species, or should be regarded as a separate one. Only two fragmentary pieces are known, and these appear to be rather young. The plant is, however, in several respects closely allied with *G. Brassica-florida*, and, therefore, I place it as a form of the latter until older specimens may be known. It somewhat differs from typical specimens of the species both in habit and structure, but on the other hand it must be borne in mind that *G. Brassica-florida* is a rather varying plant both in habit and even in structure, in the latter respect owing to the fact that it is frequently attacked by lower animals, especially worms, which nearly always show a disturbing influence on the normal development of the layers of tissue.

It is unknown under what conditions f. *laccadivica* appears, probably however in the lower part of the littoral zone, or in shallow water in rather sheltered habitats. It bears ripe sporangia towards the end of July.

Locality. The Maldives: Hulule, Male Atoll, a quite young and sterile specimen appears to belong to the form in question; and the Laccadives: Minikoi Atoll.

9. *G. Fosliei* (Heydr.) Fosl. (Plate XXV. fig. 3).

In *Videnskr. Selsk. Skr.* 1901, No. 2, p. 8.

Lithothamnion Fosliei Heydr. in *Ber. Deutsch. Bot. Ges.* 1897, p. 58; ex parte sec. spec.; *Lithophyllum Fosliei* Heydr. *l.c.* p. 410.

As remarked by me (*l.c.*) this species in part included an *Archaeolithothamnion.* According to remarks of its author it properly is a *Lithophyllum*, but the latter genus includes in his opinion also *Goniolithon.* Therefore, I here refer the species to this genus, in part according to an authentic specimen that I possess, in addition to the specimens in this collection. It appears, however, to me to be a question whether the species does not represent a new subgenus of *Goniolithon*, as the carpospores in some respects differ from the type of the latter, but the significance and value of this difference is not yet fully known.

The species in several respects comes near to *Goniolithon Notarisii*, especially in regard to the sporangia. The last-named organs have till now been unknown. In one of the specimens from the Laccadives I met with conceptacles of sporangia, and in another with conceptacles of cystocarps. The former are 450—650 μ in diameter seen from above, thus rather smaller but of the same shape as the conceptacles of cystocarps, which are 800—1100 μ in diameter. The sporangia are four-parted, 70—80 μ long and 30—40 μ broad.

As far as hitherto known the species frequently sticks to corals in the uppermost part of the sublittoral zone, and perhaps also in the littoral zone. It appears to grow in company with other species, sometimes even anastomosing with these, such as *Lithophyllum craspedium* and *L. oncodes.* Plate XXV. fig. 3 shows a rather young specimen attached to a coral. In the Laccadives the plant is provided with reproductive organs towards the end of July.

Locality. The Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll.

EXPLANATION OF PLATES XXIV—XXV.

All the figures from photographs in natural size.

Plate XXIV.

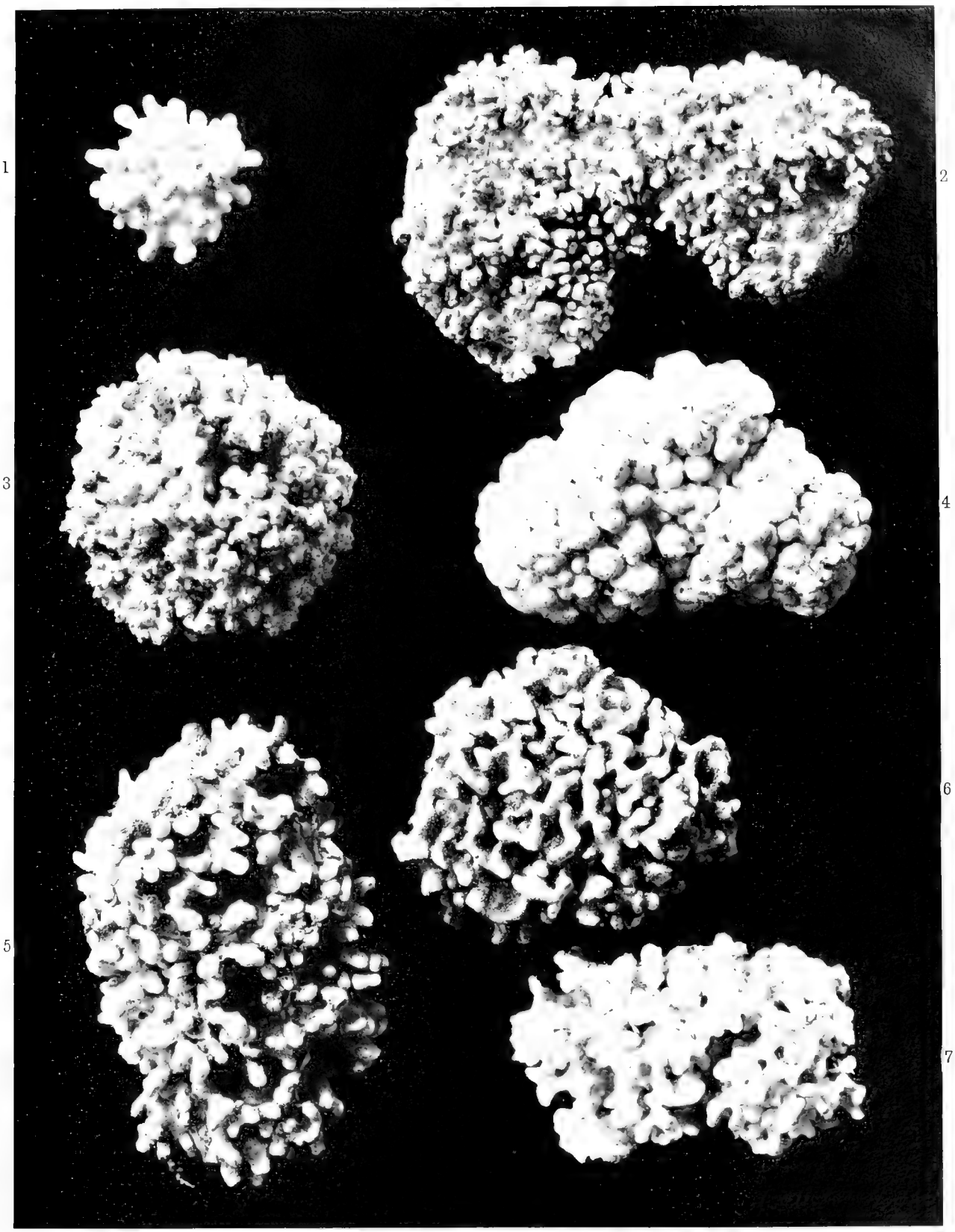
Fig. 1. *Archaeolithothamnion Schmidtii* f. *dissita* Fosl. An apparently young specimen, almost surrounding a coral.

Fig. 2. *Lithothamnion fruticulosum* (Kütz.) Fosl. f. *crassiuscula* Fosl. A fully developed specimen, attached to a coral.

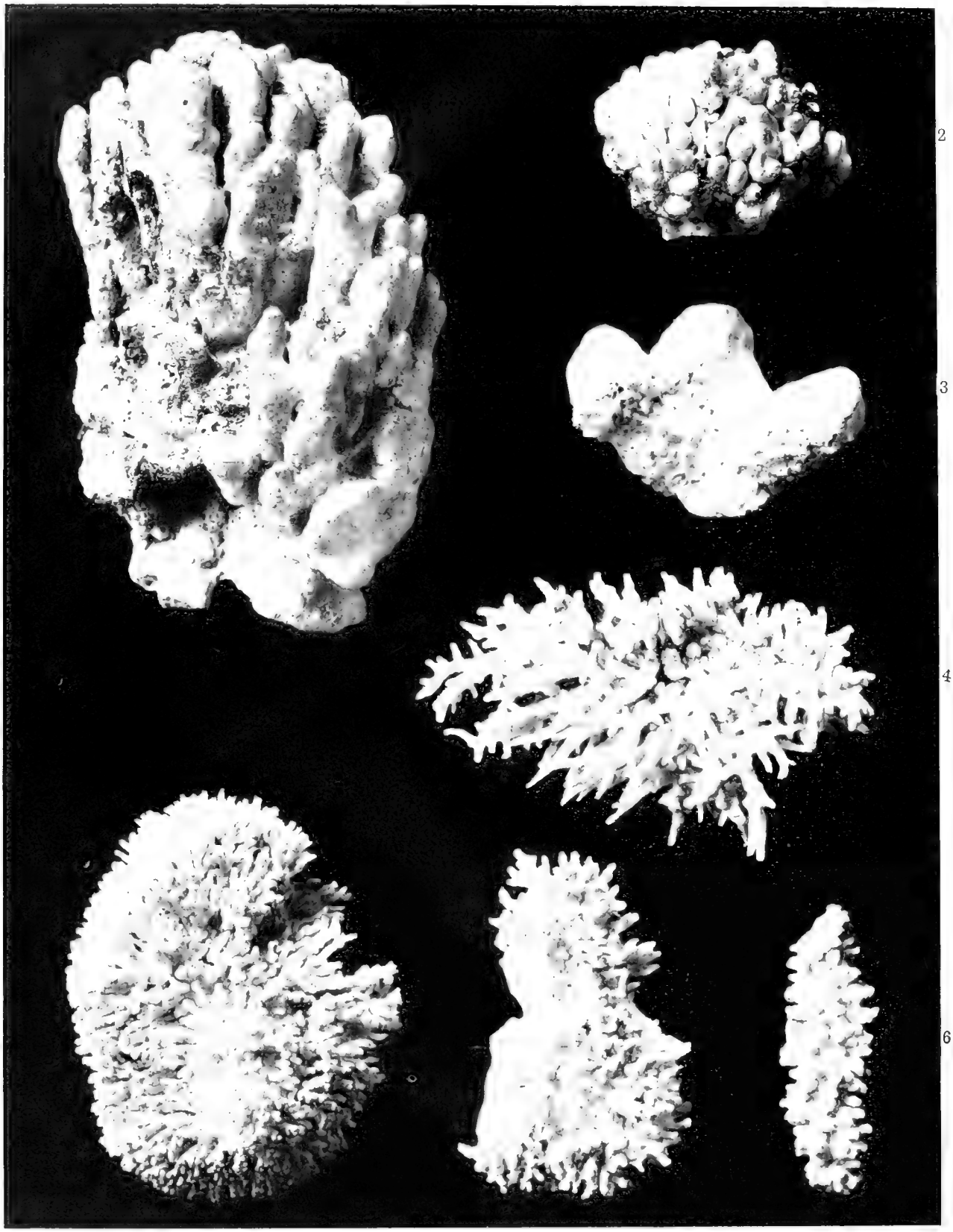
Fig. 3. *Lithothamnion fruticulosum* (Kütz.) Fosl. forma. An almost spherical specimen of a rather hard consistency, with rather numerous partly overgrown Polyzoa and other animals.

Fig. 4. *Lithophyllum Reinboldi* A. Web. et Fosl. A rather young but typically developed specimen, attached to a coral.

Fig. 5. *Lithophyllum Kaiserii* Heydr. A coarse form of the species.



FOSLIE LITHOTHAMNIA.



FOSLIE —LITHOTHAMNIA

FIG. 6. *Lithophyllum Kaiserii* Heydr. A coarse specimen of a form most nearly related to f. *subplicata* Fosl.

FIG. 7. *Lithophyllum Kaiserii* Heydr. An almost typically developed specimen of the species.

PLATE XXV.

FIG. 1. *Lithophyllum craspedium* f. *compressa* Fosl. A rather typical specimen of the form.

FIG. 2. *Lithophyllum craspedium* f. *abbreviata* Fosl. A fully developed specimen, showing the transition to f. *subtilis* Fosl.

FIG. 3. *Goniolithon Fosliei* (Heydr.) Fosl. A rather young specimen of the species, attached to a coral.

FIG. 4. *Goniolithon frutescens* Fosl. f. *typica*. An apparently freely developed specimen of the plant.

FIG. 5. *Goniolithon frutescens* f. *congesta* Fosl. A roundish or almost subhemispheric specimen with a coral nucleus.

FIG. 6. *Goniolithon frutescens* f. *congesta* Fosl. A young specimen sticking to a coral, giving transition to f. *typica*.

FIG. 7. *Goniolithon Brassica-florida* (Harv.) Fosl. f. *laccadivica* Fosl. A rather young specimen, surrounding a branch of a coral.

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The Fauna and Geography of the Maldive and Laccadive Archipelagoes

Being the Account of the Work carried on and of the Collections made by an Expedition during the years 1899 and 1900

Edited by

J. Stanley Gardiner, M.A.

Fellow of Gonville and Caius College and late Balfour Student of the University of Cambridge.

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With Plates I—XXV and Text-Illustrations 1—119

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PREFACE.

In March, 1899, I left England, in pursuance of my appointment as Balfour Student of the University of Cambridge, with a commission to explore and investigate the Coral Reefs of the Laccadives, Maldives, and Ceylon. As the south-west monsoon is unsuitable for work from small craft in the Indian Ocean, it was proposed to devote the summer of 1899 to a thorough survey of the atoll of Minikoi, the most southern reef of the Laccadives. In regard to subsequent work the Managers of the Balfour Studentship gave me complete latitude to do as might seem fit.

Subsequent donations of £300 from the Government Grant, administered by the Royal Society, and of £30 from the British Association, decided me to proceed in October to the Maldive Archipelago for an extended winter cruise. The latter was entirely successful in its main results, although the expedition was considerably curtailed and seriously crippled owing to the general rise in prices caused by the war in South Africa.

I would like here to express the indebtedness of my party to His Excellency Sir E. Noel Walker, K.C.M.G., late Acting-Governor of Ceylon; to the Hon. Mr Taylor, C.M.G., late Acting-Colonial Secretary; to His Highness Mohammadu Imaduddin, Sultan of the Maldives, and his Viziers; to the Board of Trade for passages to and fro between Ceylon and Minikoi; to Capt. Channer, R.N., formerly an officer of H.M.S. Challenger, now Superintendent of Lighthouses in the Ceylon district, for many valuable hints and much local information; to Sheikh Jeevunjee Noorbhai for his generous help and assistance during the time we were in the Maldives; to Rear-Admiral Sir W. Wharton,

Hydrographer, for advice and loan of scientific instruments; to Dr David Sharp for taking charge of the insect collections; to Sir John Murray, K.C.B., Prof. Judd and Prof. Agassiz for advice and assistance in many ways; and indeed to all kind friends and contributors for their aid.

Above all I wish to acknowledge the great obligations of myself and my party to Mr Adam Sedgwick for his great assistance and very active interest in the progress and work of the expedition.

In the work I was voluntarily assisted by Mr L. A. Borradaile (Selwyn College) and Mr C. Forster Cooper (Trinity College), who have largely contributed to whatever measure of success may have been attained. During five weeks in March and April, 1900, Mr Forster Cooper took charge of the work single-handed at a time when I was incapacitated by fever. My thanks are also due to Capt. Molony, S.S. Ileafaee, for his help in surveying Suvadiva and Addu atolls; and further to Mr Geo. Sheldrake, in charge of S.S. Thrunscoe, during our visit stranded on Minikoi, for practical help on many occasions.

J. STANLEY GARDINER.

August, 1901.

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